POWER PLANT ENGINEERING

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The New Plant of the Fisher Body Ohio Co.

NEW POWER PLANT FOR THE LARGEST SINGLE UNIT AUTOMOBILE BODY MANUFACTURING PLANT IN THE WORLD EXEMPLIFIES MODERN CONSTRUCTION IN ITS HIGHEST DEGREE

THE NEW MANUFACTURING plant of the Fisher Body Ohio Co. at Cleveland, Ohio, is, without doubt, one of the most excellent examples of modern industrial plant construction that it is possible to find anywhere. This is the largest single unit automobile body manufacturing plant in the world. It was erected, entirely new, and on a new site, during 1920 and 1921 at a cost of over $8,000,000, and as it stands today there are contained in the building over one million sq. ft. of floor space. The main factory building alone is 1150 ft. in length and six stories in height. The ground area upon which the new factory is located is sufficient, however, so that if it becomes necessary at some time in the future to enlarge the plant, additional buildings may be erected to make a plant five times the size of the present unit.

While at present no attempt is being made to generate the electrical energy required for manufacturing purposes in this plant, it is obvious that the heating and water service requirements alone would necessitate the provision of a power plant of no small size.

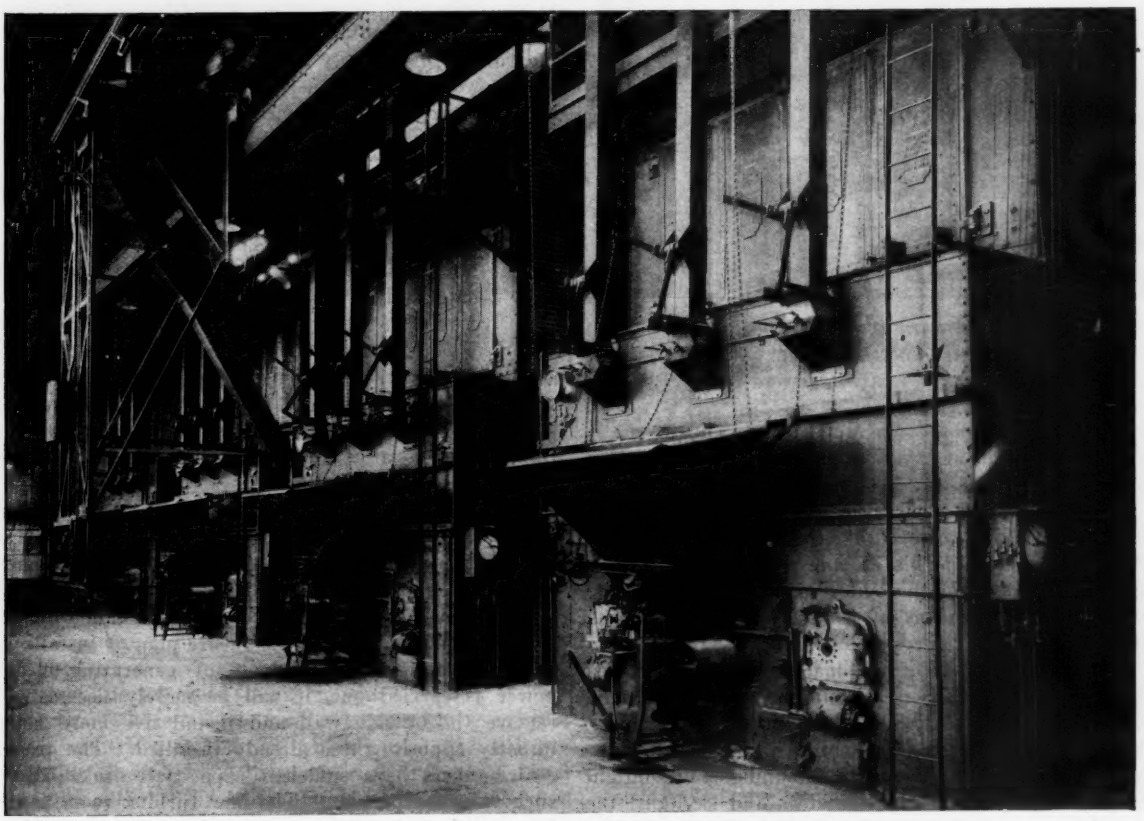


FIG. 1. VIEW IN THE BOILER ROOM, SHOWING COMBINATION COAL AND WOOD BURNING BOILERS

In addition to the heat and water service delivered to the factory buildings, the power plant also furnishes compressed air and hydraulic power for certain manufacturing operations. It is the intention of the manage-

ment, however, to generate also their own electricity in time to come, and provision has, therefore, been made to add a turbine room together with additional boiler capacity to the plant. The nature of the addition will be more thoroughly discussed elsewhere in this article.

General Features of the Power Plant

The power plant building is of brick, steel and concrete construction about 114 ft. in length by 93 ft. wide. The foundation is of reinforced concrete. Although the plant is essentially a single building there are two general divisions, the boiler room and the machine room. From the common machine and boiler room floor level, the machine room measures 33½ ft. in height, the boiler room, 44 ft. and the top of the coal conveying gallery about 62 ft. All parts of the building including the coal conveyor gallery and the basement rooms are amply lighted by large windows. Skylights above the machine room provide additional natural illumination in that portion of the plant.

As may be seen by referring to the exterior view of the power plant, Fig. 5, a large steel water tower is

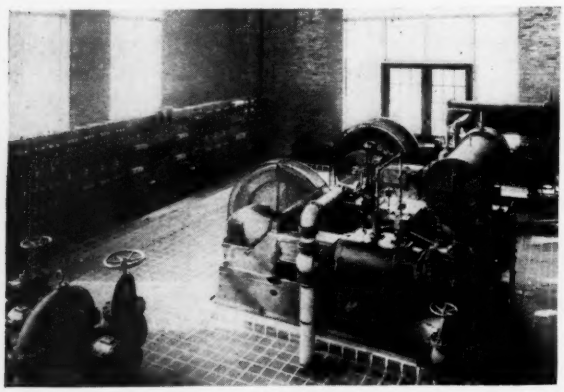


FIG. 2. GENERAL VIEW IN MACHINE ROOM, SHOWING AIR COMPRESSORS AND CONTROL BOARD. HOT WATER CIRCULATING PUMPS AT LOWER LEFT

located adjacent to the machine room. This tower is 190 ft. in height and is installed for fire protection purposes only.

A 225-ft. radial-brick, Custodis chimney 11 ft. in diameter serves to remove the products of combustion from the furnaces. This chimney as may be seen is located at one end of the boiler room and is connected to the boilers by means of a tapered steel breeching installed above the boilers.

The interior walls of the machine room are faced with a brownish glazed brick, while the floor is of square, red tile laid in cement and spaced about ½ in. apart. This gives an exceptionally attractive and neat appearance and on a bright day with an abundance of sunlight entering through the large windows and skylight, the machine room is as pleasant and bright a place as one could wish for. When one visits this spacious, light, airy room, where artificial lights have no place during the daylight hours, and then allows his thoughts to revert back to the dark, dank, smelly underground affairs called engine rooms, of days gone by, we can realize, to some extent, the immense progress which has been made in power plant design in later years. There never was any logical reason for not making the power plant as light and airy as possible, unless, perhaps, it was the hereditary influence of our cavemen ancestors that still impelled us to seek dark holes in which to live out our existence.

Fuel

On account of the great amount of wood waste in the form of sawdust, chips, shavings, etc., resulting from the manufacture of automobile bodies, it was but natural that in a plant of this type some provision should be made whereby such waste might be used economically as fuel under the boilers. And such has been the case; in fact, when the factory is operating at normal capacity, wood waste is to be used exclusively. When operating below normal capacity, however, there is not sufficient wood waste available to furnish fuel for all of the furnaces, and as a consequence, coal is also used as fuel. There are thus two separate fuel handling systems, one which is an elaborate system of blowers, cyclones and conveyors for handling wood, and the other a standard coal handling system.

The Boiler Room

The boiler room is approximately 114 ft. long by 55 ft. wide. Steam generating equipment consists of five 550-hp. horizontal water tube boilers, set singly in one row approximately 21 ft. between centers. These boilers, which were made by the Union Iron Works, of Erie, Pa., are built for a steam pressure of 199 lb. per sq. in. and have a heating surface of 5663 sq ft. They are equipped with Combustion Engineering Co. Type E stokers for burning coal and set in a dutch oven type of furnace suitable for burning wood. The setting is exceptionally high in order to obtain a large furnace volume to facilitate burning wood. No superheaters have been installed. For keeping the tubes clear of soot, five units of Vulcan soot blowers are fitted to each boiler. Each drum, of which there are two to a boiler, is equipped with a 4½-in. Homestead safety valve vented to the atmosphere. The boilers are equipped with 3-in-1 draft gages and Reliance water columns. Besides the usual steam gage, each boiler is equipped with a Bailey boiler meter.

As shown in the sectional elevation of the building, Fig. 3, the boilers are arranged along one side of the room with the fronts facing the windows. This insures abundant natural illumination. The steel, parabolic, overhead coal bunker, it will be seen, is installed directly above the firing aisle. If the future plan of installing a turbine room for the purpose of generating electric power is carried out, it will be merely necessary to remove the outside wall and install five more boilers directly opposite those already installed. The present coal bunkers have sufficient capacity to take care of such future expansion. The new turbine room according to this plan would be located on the same side of the building as the future boilers, thus making the future half of the building symmetrical with the present building.

Before proceeding with the description of steam headers and piping systems, we will take up the method of handling fuel.

Coal Handling Apparatus

Coal is delivered from railroad cars into a track hopper adjacent to one end of the boiler room, from which it discharges into an apron conveyor which in turn carries it to a double roll crusher. This crusher which has a normal rated capacity of 25 T. per hr. and is driven by a 25-hp. Allis-Chalmers induction motor, delivers the fine coal to an 18 by 24-in. pivoted bucket conveyor. The conveyor travels a rectangular path around the boiler house, and at the upper run discharges into the overhead coal bunkers through the agency of a movable tripper. The lower run of the conveyor is installed in a covered duct in the boiler room basement, where it is also used in disposing of the ashes.

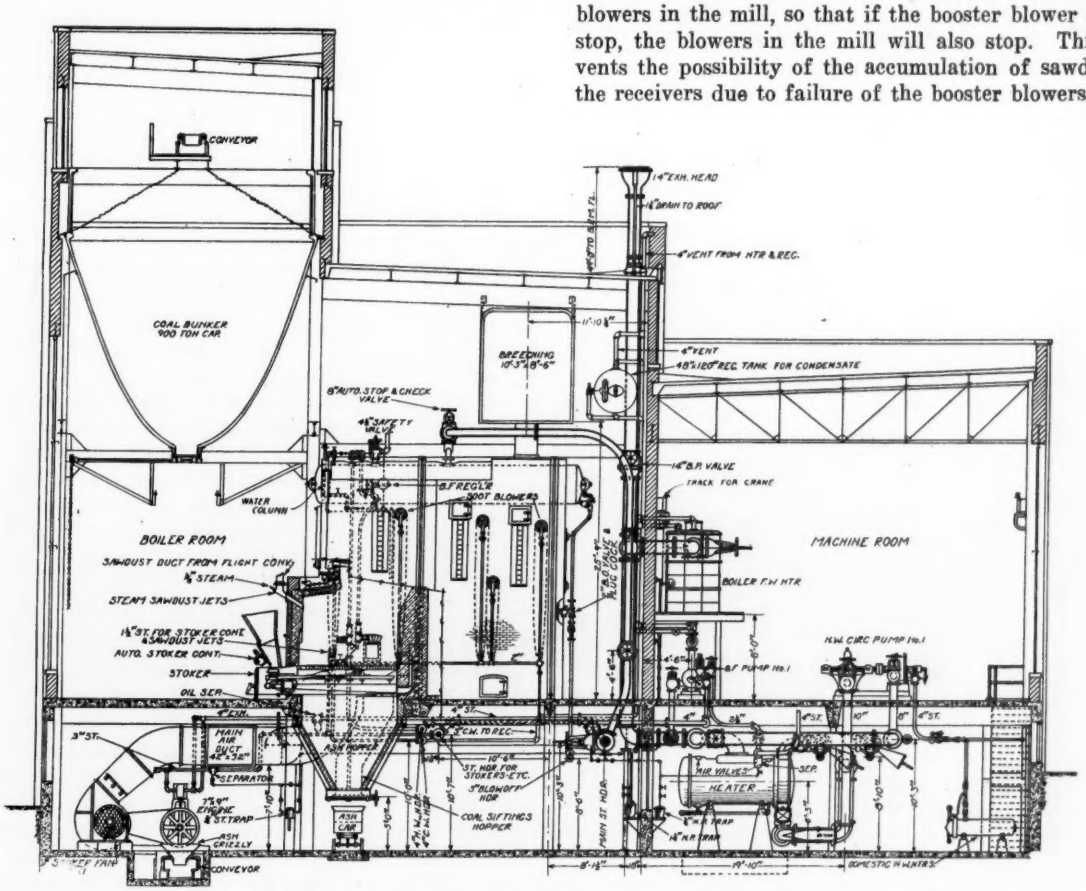


FIG. 3. CROSS SECTIONAL ELEVATION OF THE POWER PLANT

A 15-hp. Allis-Chalmers induction motor is used to operate the conveyor system.

From the overhead bunkers, which have a storage capacity of 900 to 1000 T., coal is delivered by gravity to a 2-T. electric weigh larry, which after automatically recording the weight, delivers the coal to the individual stoker hoppers. The weigh larry runs the length of the boiler room and is controlled from the boiler room floor, as may be seen by reference to Fig. 1. It is operated by a 5-hp. electric motor.

Handling the Wood Fuel

Sawdust and other wood refuse from the wood working machines in the mill buildings is blown by the individual blowers on each machine into the four large receivers shown in Fig. 7. This equipment was furnished by the Grand Rapids Blowpipe and Dust Arrester Co. These receivers, it will be seen, are installed upon a platform in the yard outside of the mill buildings, and act as intermediate receivers between the wood working machines and the cyclones on top of the power house. Two large blowers, each driven by 50-hp. induction motors and installed in the small out-house shown in Fig. 7, remove the sawdust from the receivers and blow it up to the cyclones on the roof of the power house. The latter are shown in the exterior photograph, Fig. 5.

The method of operation of this blower system is of interest. The two electrically driven booster blowers in the out-house are electrically interlocked with the blowers in the mill, so that if the booster blower should stop, the blowers in the mill will also stop. This prevents the possibility of the accumulation of sawdust in the receivers due to failure of the booster blowers. The latter are entirely automatic in operation and under ordinary conditions require little or no attention. Since sawdust is to form the bulk of the fuel to be burned it is evident that the blower system must have considerable capacity.

From the cyclones on top of the power house, the wood fuel drops by gravity into an overhead bunker located at one end of the coal bunker. A number of drag chains installed in this bunker prevent the sawdust from caking and arching and scrape it into a flight conveyor which runs the length of the boiler room across the boiler fronts. Three spouts extend downward from this flight conveyor to each furnace, as may be clearly seen in the photograph, Fig. 1. Sawdust drops through

these spouts by gravity and is ejected into the furnaces by two ⅜-in. steam jets located at a point where the sawdust spouts enter the furnaces. All sawdust not delivered to the furnace spouts is discharged into a small bucket elevator which delivers it back into the sawdust bunker. The flight conveyor is driven by a 7½-hp. electric motor and the bucket elevator by a 3-hp. motor, both of Allis-Chalmers make.

With the exception of the parabolic coal bunker, which was furnished by the R. H. Beaumont Co., all coal handling, coal crushing and sawdust handling apparatus was supplied by the Stephens-Adamson Mfg. Co.

The amount of sawdust delivered to the furnace through each spout is controlled by means of a hand-operated slide, just above the steam jets. These, as can be seen in Fig. 1, are chain operated from the fireroom floor.

Ash Handling

Ashes is delivered by gravity from the ash hoppers in the basement underneath the boilers into hand cars which run on tracks below the hoppers. Figure 8 illustrates this to good advantage. The ash gates are hand

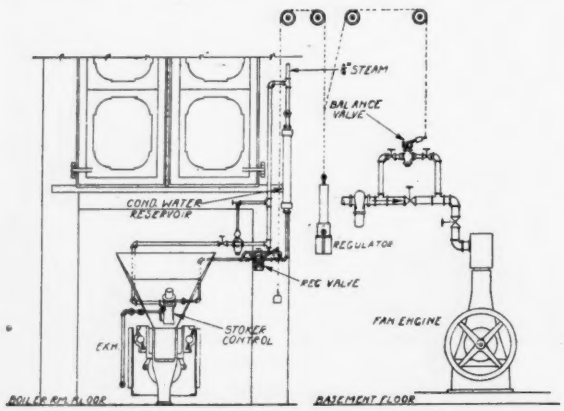


FIG. 4. DIAGRAM SHOWING STOKER AND FAN ENGINE REGULATOR

operated through rack and pinions as shown. When filled, the ash cars are wheeled to either of two small turntables, where they are turned through 90 deg. and then wheeled to an ash grizzly. Ashes dumped into these grizzlies are delivered to the pivoted bucket conveyor running in a covered duct described in connection with the coal handling equipment. It is obvious, of course, that the ashes must be removed at a time when the conveyor is not being used in filling the coal bunkers. From the grizzlies, the bucket conveyor carries the ashes up to a bunker located over the railroad track into which it is discharged, and from this hopper the ashes is delivered by gravity into the railroad cars below.

Forced Draft

Forced draft for the furnaces is supplied by two Bayley fans each having a capacity of about 40,000 cu. ft. per min. These fans are located in the basement of the boiler room as shown in Figs. 3 and 10, and are each driven by an 80-hp. 7 by 9-in. vertical, Troy engine through Poole Turbo gears. The gears increase the engine speed of 90 r.p.m. to 600 r.p.m. on the fan shaft. Each fan delivers air into the main air duct, from which five branches are taken off, each branch supplying a boiler. The air duct is of steel 42 by 52 in. and is tapered at both ends as shown in Fig. 10. Air for the furnaces is controlled by dampers, located in each of the five air ducts leading to the furnaces.

The speed of the fan engines, as well as the speed of the stoker rams on the floor above, is automatically controlled by a steam pressure regulator, as shown in Fig. 4. The master regulator, it will be seen, is connected to the steam supply lines of both fan engine and stoker rams.

High Pressure Steam Piping and Boiler Headers

Steam is taken from the boilers through 8-in. automatic stop and check valves and through 8-in. vertical headers which connect with the main steam header in the basement. This arrangement is illustrated in Figs. 3 and 10. At a point 4 ft. 6 in. above the boiler room floor each boiler header is fitted with an 8-in. extra heavy, outside stem, gate valve.

The main steam header is a 12-in. high pressure line located in the basement along the boiler room wall. It is so arranged, however, that if in the future five additional boilers are installed on the other side of the firing aisle, as explained previously, it may be extended around the entire boiler room basement in the form of a loop.

All steam piping throughout the plant is covered with 85 per cent magnesia insulation; all cold piping is covered with felt paper and 3-cell pipe covering.

An auxiliary 4-in. steam line which is supplied from the main header, furnishes steam for operating the soot blowers, the stoker rams and the forced draft fans.

Boiler Blowoff Piping

Each of the two drums on the boilers are fitted with a 2-in. blowoff valve and a 1-in. surface blowoff valve and plug cock. The rear headers are fitted with three, 2-in. blowoff valves. The entire blowoff system on each boiler connects into a 2½-in. vertical line which in turn connects to the 3-in. blowoff header in the boiler room basement. This line extends the length of the building and discharges into a 42 by 60-in. vertical blowoff tank as shown in Fig. 10. From the tank, the water finds its way to the sewer through a 6-in. line, while a 5-in. line vents the tank to the atmosphere.

Boiler Feed Water

Water is delivered to the boilers by two Lea-Courtenay 3-stage centrifugal pumps, rated at 250 gal. per min. under a 225-ft. head and driven by 70-hp. Moore steam turbines at 2800 r.p.m. These pumps, as may be seen by referring to Fig. 3, are located in the machine room under the feed water heater which is mounted on a platform 8 ft. above the floor. Three-inch discharge lines from the pumps pass downward through the floor and connect into a 4-in. main feed water header, running lengthwise along the ceiling in the boiler room basement. Five 3-in. branches from this header pass up through the floor where each one branches off into two separate 2-in. feed lines to the boiler. Either of the two feed lines may be used at will. One of them,

however, is provided with an automatic feed water regulator of the float type, while the other line is hand regulated. There are thus two separate feed lines to each boiler.

A 4-in. cold water header located in the basement immediately below the feed water header is provided for the purpose of admitting cold water to the boilers when necessary. Five branch lines from the cold water header connect with the 3-in. feed water line just below the point where it divides into two systems. By simply opening a valve, cold water may be sent into the boilers through either of the two feed lines.

A 48 by 120-in. receiving tank, located in the boiler room about 26 ft. above the floor receives the condensate from the steam lines in the factory buildings, the dry kiln, the hot water heaters, etc. This condensate is used as boiler feed, discharging by gravity into the feed water heater below. In case the amount of condensate in this tank is insufficient to provide the requisite quantity of boiler feed, cold water is delivered into the tank through a 3-in. line connecting with the 4-in. cold water header in the basement, referred to previously. The cold water supply to the tank is automatically controlled by means of a float.

The feed water heater is an open Cochrane heater, rated at 3000 hp. and equipped with a V-notch meter. Feed water is heated by exhaust steam from the machine room equipment. All of the exhaust steam, however, is not available for heating boiler feed water, since there are installed in the basement three large heaters for building heating service which also are heated by exhaust steam. Provision is therefore made for introducing live steam into the exhaust header through reducing valves as shown in Fig. 10. The latter are provided with a 6-in. bypass for feeding live steam into the exhaust system by hand in case of failure of the reducing valves.

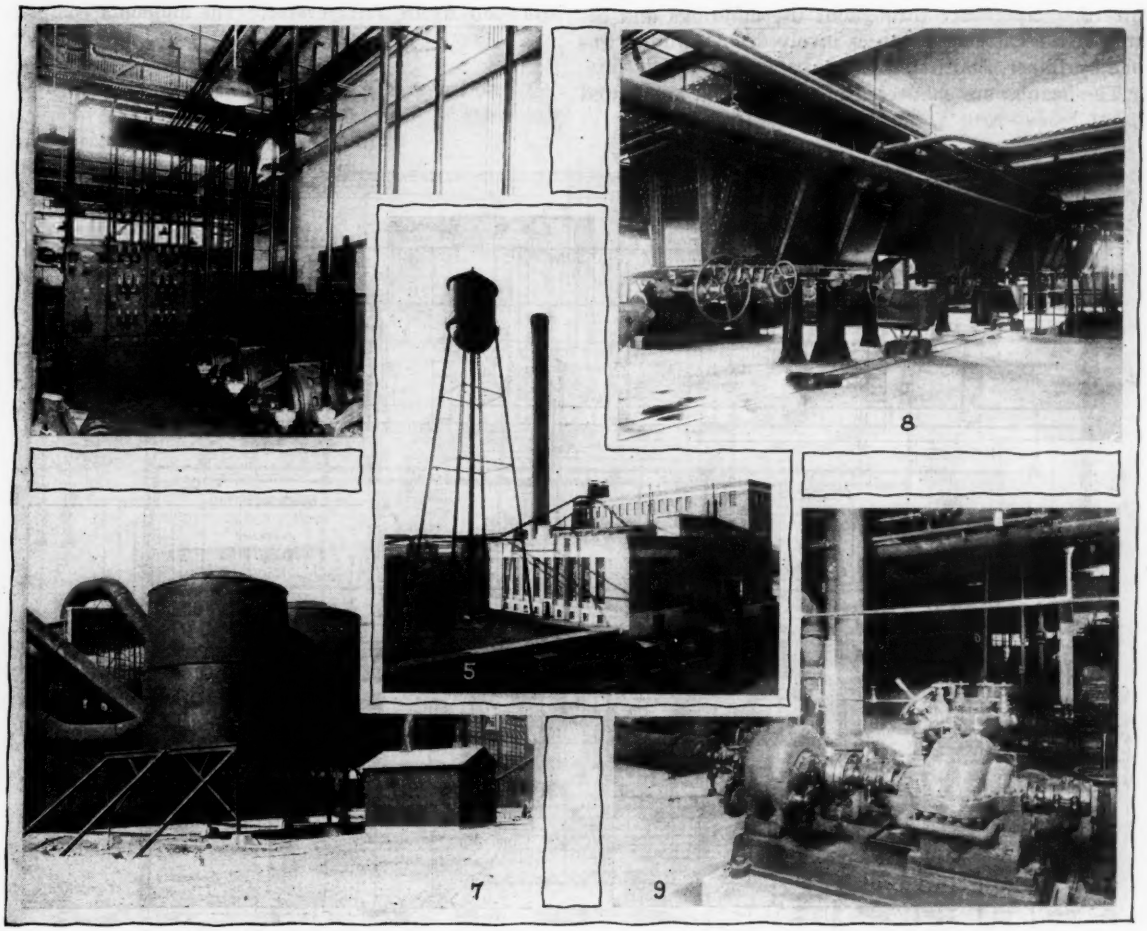


FIG. 5, EXTERIOR VIEW OF PLANT. FIG. 6, FREQUENCY CHANGER INSTALLATION IN FACTORY. FIG. 7, SAWDUST RECEIVERS AND BOOSTER BLOWER HOUSE. FIG. 8, BOILER ROOM BASEMENT SHOWING ASH HOPPERS. FIG. 9, VIEW IN MACHINE ROOM BASEMENT SHOWING FIRE PUMP IN FOREGROUND

Condensate from the three closed heaters just referred to collects in a 58 by 84-in. receiving tank, located in a pit in the basement of the boiler room. This water is raised to the overhead receiving tank in the boiler room for further delivery to the feed water heater, by two centrifugal pumps, also located in the pit. One of the pumps is electrically driven while the other is steam driven. As a precautionary measure this condensate tank is furthermore so arranged that, if, due to failure of both condensate pumps, the tank should tend to fill up, compressed air from the main compressed

air system can be admitted to the tank and the water raised to the upper tank in that manner.

It is probably evident to the reader that reliability and absolute protection against interrupted service has been one of the primary aims in installing the equipment throughout this plant. Duplicate or even triplicate equipment has been installed wherever possible.

Heating System

The heating system installed at this plant is a forced hot water circulating system, served by three closed type Alberger heaters located in the basement of the machine room. This type of heating system was installed because of the necessity of maintaining a uniform temperature throughout the buildings and because of the extreme distances involved. All piping was done by Baker, Smith and Co.

The heaters are connected in parallel and are heated as stated elsewhere in this article by exhaust steam or by steam from the high pressure steam line through suitable reducing valves. They are each capable of handling 3000 gal. of water per min., and are designed to operate on steam pressures varying between atmospheric and 25 lb. per sq. in.

Water is circulated in the heating system by three 500-gal. per min. 140-ft. head, Kingsford centrifugal pumps driven by 175-hp. Kerr steam turbines. These pumps operate normally at 1800 r.p.m., and under average conditions of temperature, maintain a velocity of circulation of about 10 ft. per sec. Twelve-inch mains carry this water to and from the main building while smaller lines serve the mill. These are shown in the plan view, Fig. 10.

Domestic hot water is furnished by two Alberger heaters of the closed type of 400 gal. per min. capacity each. These heaters are heated by live steam at from 50 to 150 deg. F. under thermostatic control. This system is served by a 75-gal. per min. 30-ft. head. Goulds centrifugal pump, driven by a 440-v. 3-phase, 60-cycle General Electric induction motor.

Drinking Water

Drinking water for use in the factory is cooled by a 10-ton Arctic refrigerator. The ammonia compressor is driven by a 35-hp. G. E. induction motor through Poole Eng. and Mfg. Co. reduction gears having a speed ratio of 680—80 r.p.m. The ammonia condenser is of the double pipe type. The cooling tank for the drinking water has a capacity of 500 gal. and is glass lined. Water is circulated through the buildings by a motor driven Deming, triplex pump having a capacity of 25 gal. per min. The latter, together with two 100 gal. per min. Goulds centrifugal cold water booster pumps are located in the machine room basement adjacent to the domestic hot water heaters. One of the booster

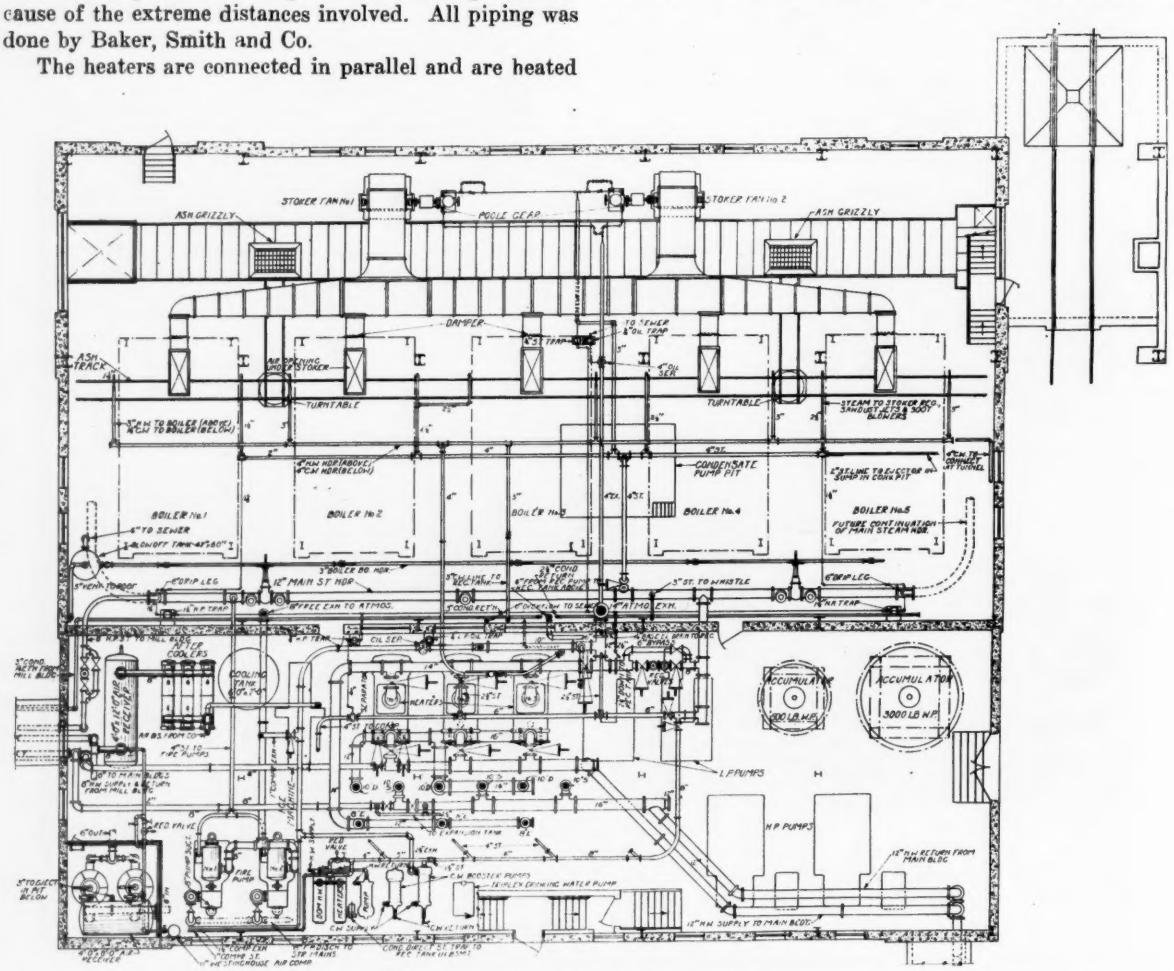


FIG. 10. BASEMENT FLOOR PLAN SHOWING PIPING

pumps is motor driven while the other is direct connected to a 7-hp. 2300-r.p.m. steam turbine.

Hydraulic Power

Certain stamping processes in the manufacture of automobile bodies require hydraulic pressure. At the Fisher Body Ohio Co. this service is supplied by two duplicate sets of hydraulic pumps together with hydraulic accumulators. One set, the high pressure set, as it is called at the plant, consists of two 3000-lb. 40 gal. per min. reciprocating hydraulic pumps driven by 150-hp. General Electric motors. The other two pumps are for 500 lb. service, driven by 30-hp. motors. Two accumulators are provided, one for the 500 lb. service and the other for 3000 lb. service. The hydraulic equipment was furnished by the Chas. F. Elmes Co. of Chicago.

For protection in case of fire, two Dayton-Dowd Co. centrifugal fire pumps are provided. One of these has a capacity of 1000 gal. per min. at 125 lb. pressure, while the other can handle just under 1500 gal. of water per min. Both are driven by 125-hp. Kerr steam turbines at 1800 r.p.m. The exhaust steam from the driving turbines is not delivered to the common exhaust system as is that of the other turbines but is discharged directly to the atmosphere. Both fire pumps deliver water to an 8-in. main directly connected to the fire protection system. Steam for the turbines is taken directly from the main steam header through a 4-in. line, thus reducing possibility of failure to the steam supply line to a minimum.

Drainage throughout the entire manufacturing plant is taken care of by two compressed air sewage ejectors. These, as shown in Fig. 10, are located in the machine room basement in a pit. Compressed air for this purpose is furnished by a small 11-in. Westinghouse steam driven air compressor of the locomotive type. This air is first delivered to a 4 by 8-ft. receiver located directly above the ejector pit. In case of failure of the small locomotive compressor, air may be supplied to the ejectors from the main compressed air system through a reducing valve. The latter is provided with a bypass to insure additional reliability.

Compressed Air

Compressed air for factory service is supplied by two 1000-cu. ft. per min. cross compound Bury air compressors. These are located in the machine room as shown in the accompanying drawings and photographs. One is a steam driven unit, 14 by 21 by 20 by 12 by 14-in. while the other is a 14 by 14 by 12 by 14-in. unit direct connected to a 185-hp. 440-v. 3-phase, 60 cycle General Electric self-starting synchronous motor.

Both machines deliver air at a pressure of 125 lb. per sq. in. through 5-in. discharge lines to 3 after coolers and thence into a 4 by 12-ft. air receiver. The aftercoolers and receivers are located in the basement underneath the compressors. From the receiver, 6-in. air lines lead to the factory buildings.

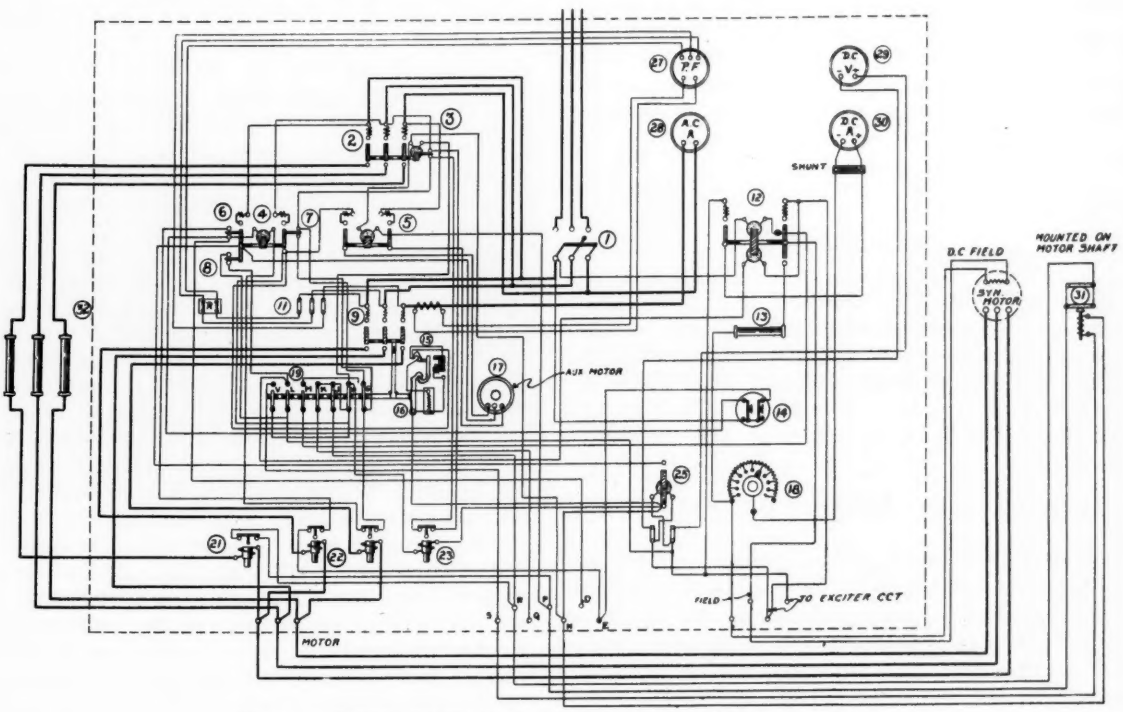


FIG. 11. WIRING DIAGRAM OF SYNCHRONOUS MOTOR-STARTING PANEL

Electrical Features

With an electrical load of 4000 kw. for lighting purposes and 6000 kw. for power purposes, the electrical system at the Fisher Body Ohio Co. is quite elaborate. As stated at the beginning of this article, no electricity is generated at the present time, the entire supply being delivered to the main primary switchboard from the Cleveland Electric Illuminating Co. over two 11,000-v. 3-phase circuits. The main primary switchboard is of the manually operated, remote control, con-

crete-cell type and is located in the basement of the mill building. The two incoming 11,000-v. 3-phase circuits connect to the main primary bus through two high tension oil switches. Five primary feeder switches, also 11,000-v. oil switches, are provided, one in each of the five feeder circuits which distribute the current to the various transformer banks throughout the plant. The oil switches are separated by concrete barriers and the busses are concealed in transite compartments.

Five transformer banks are located at various places throughout the factory where the 11,000-v. primary current is stepped down to 440 v. or 220 v. for power and lighting purposes. All high voltage distribution from the primary switchboard is underground.

Current for use in the power plant is stepped down by two sets of transformers, one unit of 1000 kw. capacity for 440-v. service and one 150-kw. unit for 220 and 110-v. service.

The main control board in the machine room is shown in the photograph, Fig. 13. This is an entirely automatic control board manufactured especially for the Fisher Body Ohio Co. by the Allen-Bradley Co., of Milwaukee. The control equipment mounted on this board is of the magnetic contactor type and possesses

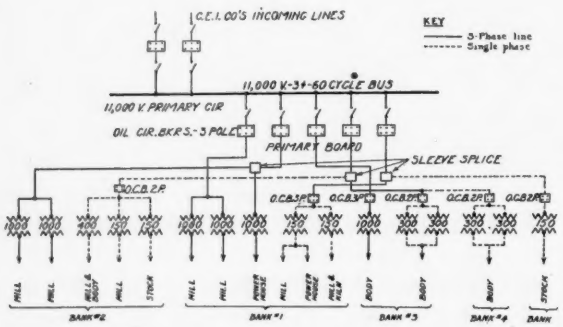


FIG. 12. SINGLE LINE DIAGRAM OF ELECTRICAL SYSTEM

some exceedingly novel and interesting features and will therefore warrant more or less detailed description.

As may be seen from the photograph, the board consists of 18 panels equipped with automatic starting and control apparatus for various driving motors throughout the power plant. All motors are remote controlled from this board by push buttons installed at the point where the motors are located.

Perhaps the most interesting features of the entire installation are the automatic starting panels for the 185-hp. synchronous motor driving one of the air compressors, and its motor-driven exciter. These are the second and third panels from the right in the photograph. This starter, as stated above, was built especially for the 185-hp. General Electric synchronous motor which can be started in a manner similar to that used in starting a squirrel cage induction motor, that is, the motor is wound with a closed rotor circuit that acts like a squirrel cage motor.

The function of the starter is to bring the synchronous motor up to speed, performing the necessary switching of the direct current field at the proper instant and connect the motor direct into the a.c. circuit with the field receiving power from the direct current exciter.

The starting resistance is of the graphite compression type and consists of six tubes each containing a column of graphite discs, the resistance of which is varied between a maximum and minimum value by means of pressure applied through pressure plugs and an equalizing mechanism, this pressure being transmitted through movable pressure plugs extending through the ends of the tubes. The pressure mechanism consists of a small squirrel cage motor located at the lower part of the panel, Fig. 13, driving the pressure mechanism through a worm gear and magnetic clutch. The pressure is applied by means of a lever passing through the panel and connected to the equalizer mechanism on the back of the panel. The pressure lever is operated by means of a cam mounted on the shaft extending from the clutch and gear box. This same shaft also carries a number of cam operated auxiliary switches (part 19 in the wiring diagram) used in performing the various switch functions.

Referring to the wiring diagram, Fig. 11, the main alternating current circuit may be traced as follows: The 3-phase lines come into the top of switch (2) and also to the top of switch (9). Switch (2) is a magnetically operated 3-pole contactor. Switch (9) is a 3-pole contactor of the same general design as (2) only it is operated by means of the same lever and cam that applies pressure to the resistance. The mechanism of the latter switch is such that it does not close until the completion of the pressure operation, when the resistance is brought to a minimum value, that is, under maximum pressure. The three a.c. lines from the bottom of the switch (2) pass through the compressor resistance units (32) and from there to the stator of the motor. One of these lines passes through a current relay (21) in series with the resistance units. The three a.c. lines from the bottom of switch (9) are also connected to the stator of the motor, two of them passing through the overload relays. In general the operation of these switches is as follows: When the "start" button (14) is pressed the clapper switch (2) closes and connects the stator to the line through the units (32) and the series relay (21). At the same time the auxiliary motor is also connected through switch (5) and starts to apply pressure to the resistance units. As this pressure is applied, the resistance in the units (32) is decreased and the motor will start to accelerate like a squirrel cage motor, and if no other conditions were to be considered the complete compression on (32) would be completed in the definite time offered by the gear reduction of the small motor which amounts to about 6 or 7 sec.; however, the relay (21) is set to prevent excessive currents and if this acceleration is too fast for the motor with its load, the relay (21) will trip and interrupt the auxiliary motor circuit so that the pressure operation is stopped and the large motor given an opportunity to accelerate without removing more resistance from its circuit. This combination of time limit and current limit acceleration is ideal and insures plenty of time to bring the motor up to speed and also prevents sudden connections of heavy loads on the line that would cause excessive line disturbances. Another protective relay is mounted on the synchronous motor shaft and is indicated by (31). This is a small shunt relay that is energized as soon as the start button is pressed. Its auxiliary contacts close when the coil

is energized and these contacts bridge the contacts on relay (21). This allows the momentary inrush to the synchronous motor, at a standstill, to start it revolving. As soon as the synchronous motor turns over a projection on its shaft trips the relay (31) and opens its contacts. This arrangement allows for sufficient current at the moment of starting and still provides for starting relay (21) giving protection during acceleration. Inasmuch as a comparatively high current is being carried through the relay (21) during the first seconds of starting this relay will be open—the result is that the combination of relays (21) and (31) is such that when the motor is first connected to the line the full effect of the starting torque necessary to overcome the inertia of the motor is obtained. As soon as the motor begins to turn over relay (21) becomes active and the combination of the time limit and the current limit acceleration is carried on as is explained above.

As the motor goes up to synchronous speed the pressure mechanism closes switch (9) and the auxiliary H opens and releases the clapper switch (2). This connects the stator directly to the alternating current lines

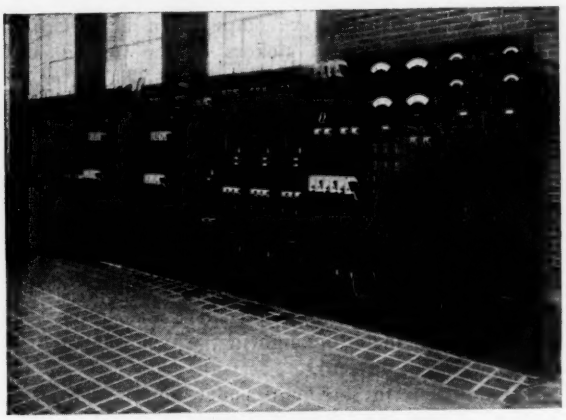


FIG. 13. MAIN CONTROL BOARD

through the overload relays (22). During the starting cycle the cam switch mechanism closes and energizes the down contact coil of switch (12) momentarily short circuiting the direct current field of the synchronous motor through the field discharge resistance (13). This action dissipates the energy accumulated in the direct current field just previous to connection of the synchronous motor directly to the line. As soon as the switch (9) connects the motor to the line the upper coil of switch (12) is energized and closes the top contacts connecting the direct current field to the exciter circuit with the field rheostat (18) in this circuit. The inter-connection of the cam switches (19) is such that the starter must be in position for correct acceleration of the motor before the start button will be effective.

This starter is interconnected with a standard squirrel cage automatic starter mounted at another position in the switchboard and is also used for starting the exciter motor generator set. When the start button is pressed this automatic squirrel cage starter accelerates the exciter and builds up the direct current supply for the field. The electrical connections are such that this automatically takes place and the exciter voltage is ready before the main operation of the synchronous starter begins. There is nothing left to the operator's judgment. He simply presses the button, the exciter is started and the synchronous motor is brought up to speed and connected properly to the line without human attention. The entire procedure requires less than 10 sec.

Frequency Changers in Factory

To provide suitable frequency alternating currents for operating induction motors in the wood working shops at various speeds, there are installed a number of motor driven frequency changers. These are shown in Fig. 6, being controlled by the five panel control board in the rear. They are of General Electric make rated at 65 kw. and will supply alternating current at frequencies varying from 65 to 105 cycles and at voltages from 440 to 197. The reason for installing these machines can probably be more readily appreciated when one considers the fact that some of the most modern types of wood working machines installed at this plant are operated by as many as 6 or 8 separate electric motor drives running at different conditions of speed, voltage and frequency.

Lighting throughout the factory is effected by incandescent units equipped with white enameled reflectors of the type shown in the accompanying photographs. Over 11,000 of such lighting units were installed.

Conclusion

The entire plant was designed and the erection superintended by Albert Kahn, architect, F. K. Boomhower and Gordon Turnbull, associate engineers of Detroit, Michigan. In concluding this article, due credit is hereby extended to the above named firm of architects and to E. F. Fisher of the Fisher Body Ohio Co., for privileges and assistance extended in the preparation of this article.

U. S. Civil Service Commission announces examinations for Junion Engineer, $1230 to $1980, civil, electrical, mechanical, signal, structural, architectural, telegraph and telephone, applications to be rated as received until further notice, to fill vacancies in the Interstate Commerce Commission in Washington, D. C., for duty in connection with the valuation of the property of common carriers, at entrance salaries indicated, and vacancies in positions requiring similar qualifications, at these or higher or lower salaries. Appointees whose services are satisfactory may be allowed the increase granted by Congress for the current fiscal year of $20 a month. Applicants must have reached their twenty-first but not their fiftieth birthday on the date of making oath to the application. These age limits do not apply to persons entitled to preference because of military or naval service. Apply for Form 1312, stating examination title.

Henry Ford states that he has made his last proposition in regard to the Muscle Shoals plant and that the matter is now up to Congress. As the proposition studied from an engineering standpoint is largely a gift to Mr. Ford, if his proposition is accepted, it is to be hoped that Congress will leave it "up" for an indefinite period.

Distributing Power Charges---I

DESCRIBING IN DETAIL AN EMERGENCY METHOD OF DISTRIBUTING POWER CHARGES IN A LARGE MANUFACTURING PLANT. BY WILFRED A. MILLER

WHEN the price of coal and wages went soaring during the years of the war, a good many managers who had never before paid more than cursory attention to their power expense began to have it impressed upon them that it was becoming a ponderable item of their total cost of manufacture. Among such plants there was one which consisted of several different mills, each of which turned out its own finished product, although all the departments were within the same grounds and were served from essentially a single power plant. Thus, the situation resembled that of several independent manufacturing establishments

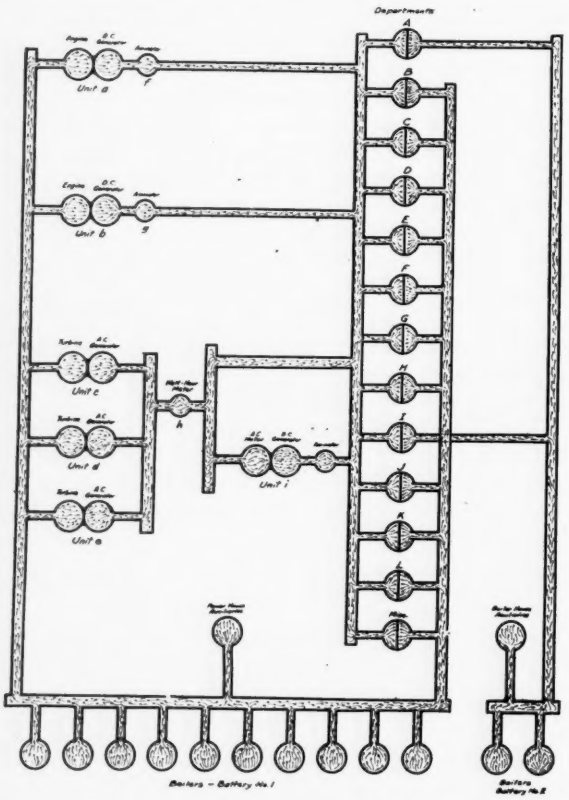


FIG. 1. DIAGRAMMATIC REPRESENTATION OF PLANT, SHOWING INTERRELATION OF POWER GENERATING AND CONSUMING CENTERS

served from one central station; however, all the departments were under a single management, and prior to the rise in costs, the power house expense was arbitrarily divided among the various mills in the plant.

This method had to be abandoned under the new conditions, a fact which was brought home very forcibly when cost-plus contracts were undertaken. It was found necessary to do something and to do it with dispatch. Of course the first solution to suggest itself was to equip the plant with meters, but this had to be abandoned for two reasons. In the first place, the time required to secure meters and to install them was an unknown quantity; certainly a matter of months. In the second place, the plant had been built up department by department, and both the piping and the wiring of the entire plant were so universally interconnected, that it would have required either an extensive remodeling of the system or the installation of a prohibitive number of meters to isolate the various power consumptions.

In view of the circumstances, it was decided that some other means would have to be resorted to, at least temporarily, until such time as a more effective remedy could be applied. A survey of the situation did not look very promising, but finally a method was worked out which proved to be very useful; so much so, in fact, that it was decided to delay the installation of meters for an indefinite period until such time at which the expense involved would be less exorbitant.

DESCRIPTION OF POWER EQUIPMENT

TO START with, there was the main power station consisting of a boiler room and generating room. The equipment of the former comprised a battery of 10 boilers with mechanical stokers under forced draft supplied by turbine driven blowers. The latter contained three turbine driven alternators generating three-phase current at 500 v. There was an additional prime mover set in the form of an engine-driven exciter, which was used only intermittently. Ordinarily excitation was supplied by a synchronous motor set. In addition to this set, there was a large motor-generator outfit for supplying direct current to the plant. The greater part of the electrical energy was supplied at 500 v. three-phase alternating current; but there was quite a considerable load, including lighting, which was furnished at 110 v. direct current.

In addition to the main boiler house there was a battery of two hand-fired boilers at a remote point in the plant, not interconnected in any way with the main supply, whose entire output was consumed for process purposes and heating by two of the departments. Of the total steam generated in the main plant, only a minor portion was taken by the alternators. Most of it passed out to the various departments, either for power or other process purposes. The process requirements were quite diversified, but the power consuming demands were few in number, though large in size. The largest was an hydraulic pump plant. This was situated in a separate building adjacent to the mill which it supplied, and might be looked upon as a separate power generating unit. The second largest demand was a Corliss engine whose entire output was used in driving one of the mills. This also was separately housed and in addition to it the engine room contained a direct current generator set. A third engine room contained a smaller hydraulic outfit and another direct current generator. The labor required for the operation of all these auxiliary power units was considered as a part of the general power expense, as the entire system was under the supervision of one chief.

POWER CONSUMPTION CENTERS

THERE WERE 12 different departments to which power, including lighting and heating, was furnished,

and in addition there was a miscellaneous use scattered about the plant, such as yard lighting, office lighting and heating, and service of a similar character. Of the 12 departments, two received all their steam from the battery of two boilers, as already stated. Of the others, nine received steam from the main boiler room, while the remaining one used no process steam, although it did have heating load in winter. The electrical energy was supplied to all from the main power house, supplemented by the small direct current stations when necessary.

When it was decided to be imperative to devise some method of power distribution which might be depended upon to give approximately correct results, an investigation of the situation was made. In going over the sources from which data might be derived, it was found that the only energy meter in use was a watt-hour meter connected in to record the entire combined output of the alternators. There were only ammeters and voltmeters on the distributing panels, and the switchboards of the two small direct current units were limited to the same equipment. It was also found that these units were tied in to the same lines that ran back to the large motor-generator set busses in the main power house.

In this connection, the writer ran into a circumstance which is a good illustration of the haphazard methods that are frequently found to exist in plants that have grown from a small beginning by making additions here and there. The presence of the engine-driven direct current generators was explained by the fact that they were installed to furnish current to their respective mills long before a main power house was thought of. With the advent of the latter, the main supply of direct current was from the motor-generator set already referred to. This consisted of a synchronous motor direct connected at either end to a large direct current generator. The motor was not designed for self starting, in consequence of which the set had to be started from the direct current side. The only sources of direct current in the power house when the motor-generator set was shut down were the two exciter sets, the one engine driven, the other driven by a synchronous condenser. With one of these reserved for excitation, the other was not of sufficient capacity to carry the starting current drawn by the big motor-generator set. To put the set into service, it was necessary to start one of the direct current generators outside of the power station in order to feed current back to the power house. Owing to the absence of an adequate starting rheostat, it was usual to cut down the line voltage at first and gradually raise it to normal as the set picked up speed. It was customary to shut down the entire alternating current equipment over Sundays, merely using the engine-driven exciter to furnish whatever current was needed for lighting. In view of the fact that the entire direct current system was tied to the same lines that connected the power station with the auxiliary generating units, it can be imagined what happened during the time required to bring the large motor-generator set into action. Another thing that arrested the writer's attention was the fact that, so far as he could discover, there was no equalizer connection between the various direct current machines in spite of the fact that they were compounded. Apparently there could have been but little overcompounding, since for the most part they ran together without trouble. Occasionally, however, they would balk when trying to parallel them and cause breakers and fuses to go out.

In addition to the electrical information mentioned, it was found that the weight of coal delivered to the boilers each day was a matter of record. At the main station, coal was delivered from storage bins to the hoppers of the stokers by means of a small traveling crane, which was equipped with a scale set at a given weight. The operator would allow coal to flow from the storage bin into the hopper on the crane until the scale was in balance and then convey the load to the boilers. He would keep track of the number of loads delivered during his shift, so that the total weight for the day could be computed from these tallies. This method gave the amount of coal delivered rather than that fired, which might cause an appreciable error during one day; but it is evident that the consumption per month could be obtained quite accurately provided the operator was careful about balancing the scale and keeping track of the number of loads handled. In the case of the smaller boiler house, the weight of coal was arrived at by keeping track of the number of barrowfuls wheeled in during the day and multiplying by an average weight per barrow. This, of course, was not expected to give highly accurate results, but served sufficiently well under the circumstances. The foregoing was the extent of the information which it was possible to secure from the power station records. The only other data available was that provided by the Engineering Department relative to water consumption and by the Factory Accounting Department relative to wages, repairs, overhead, and the like.

In considering the problem it was obvious that in order to make any distribution among the various departments a substitute method would have to be devised which would give, presumably, the same information that would otherwise have been secured by means of service meters. Two general factors were here involved. First, the normal connected load in each department and second the per cent activity over a given period as compared with the normal, the period in this case being the month. That is, if the connected load of a department were known to be 1000 hp., for example, when running at full normal capacity, and in any month only enough orders had been booked to operate 80 per cent of capacity, then it would be assumed that the power demand was only 800 hp. Or, more correctly speaking, if the energy consumption of a department were, say, 100,000 hp.-hr. per month at full capacity, then the consumption at 80 per cent activity would be only 80,000 hp.-hr.; however, before such a computation could be made it was necessary to know what constituted normal full capacity load for each department and what the per cent activity of each had been during a month.

Determining Normal Full Capacity

To get at the normal full capacity load of each department, a survey was made of all the connected load in each of them. This consisted of four parts, namely, steam for process or power, current for electric power, steam for heating buildings and current for lighting. The steam for process and power was combined as one item, since it was immaterial what manufacturing use

was made of the steam provided all that was taken from the boiler house was accounted for. Thus, the heavy steam consumption of the large hydraulic pumps was combined with the other steam consumption of the department which was served by the pumps. The steam load represented by engines and pumps could be calculated quite closely by means of indicator cards and observations of quantities pumped and pressures pumped against. The consumption of steam for other process purposes, such as drying, boiling and the like, was more difficult to arrive at; but by considering radiating surface, temperatures, capacities, and so on, figures were compiled which it was thought were a fair representation of the conditions. The steam used for power was translated into terms of pounds per hour in order to combine it with the figures on the other process steam. All estimates were of course made on the assumption that the machinery involved would operate at full capacity, although due allowance was made for the time element in operations.

The electrical energy normally used for power was arrived at by using the marked ratings of the motors and making time studies of the percentage of the time

TABLE I. DATA ENTERING INTO MONTHLY POWER EXPENSE

Symbol	Unit	Definition	Source
A	Tons	Coal used by Battery No. 1	Accounting Dept.
B	Tons	Coal used by Battery No. 2	do
C	Dollars	Coal used by Battery No. 1	do
D	Dollars	Coal used by Battery No. 2	do
E	Dollars	Total water	do
F	Dollars	Labor for Battery No. 1	do
G	Dollars	Labor for Battery No. 2	do
H	Dollars	Labor for Main Generating Room (Units c,d,e)	do
I	Dollars	Labor for Pump Room of Dept. H	do
J	Dollars	Labor for Engine Room of Dept. C (including unit a)	do
K	Dollars	Labor for Pump Room of Dept. C (including unit b)	do
L	Dollars	Total repairs	do
M	Dollars	Miscellaneous	do
N	Dollars	Burden	do

that they would normally be loaded. The motor applications were so numerous that it was assumed that the machines were of the correct capacity without checking the load. That is, if a motor was rated at 50 hp., for example, it was taken for granted that 50 hp. was being used by the apparatus driven by the motor when it was working at its capacity; however, a certain amount of judgment was exercised in accepting ratings in this manner, and in cases in which a machine was palpably over or under motored portable instruments were inserted into the lines to secure more reliable data.

The steam required for heating buildings was figured on the basis of radiation at average temperature conditions, and the current used for lighting was computed from the connected lamp capacity and the average hours of daily use.

Having ascertained the normal full capacity load of each department in the foregoing manner, the next step was to find a reliable gage of the per cent activity of each of them. This meant, first of all, establishing a standard of which to take a percentage. Several methods were suggested, one of which was to use the average monthly value of sales over an extended period preceding the time at which the determination was undertaken as a standard, and to compare each ensuing month's sales with it and thus get the percentage sought. This method had two serious drawbacks. In the first place the price of materials and labor were undergoing such radical changes that comparisons of sales figures for different periods were no indication of relative activity. Thus, the monthly sales of a mill in one month might considerably exceed those of the same month in the preceding year, and yet the mill may not have been as busy, the difference being due to a higher unit sales price. In the second place, even though sales prices had been stationary, sales in themselves could not be taken as a criterion of activity since all the product for which sales were contracted were not manufactured in the month in which the sales were made. The suggestion that value of shipments be substituted for value of sales as a basis of adjustment was open to the same objections. That is, neither method took into consideration the change in unit price nor the value of the product in process in the mill. A suggestion to use tonnage shipped as the index of activity seemed more reasonable, but this, too, was open to the fatal objection that it did not take cognizance of the in-process value of partly finished product in the mills. After careful study, it was decided that the method which combined maximum reliability with minimum labor of determination was to make use of man-hours as the basis of percentage calculations.

A representative period covering some time back was fixed upon for the purpose of establishing the standards. An analysis was then made of the Payroll Department's records covering this period, for the purpose of obtaining the total man-hours used by each mill during the period. Dividing this total by the number of months in the period gave an average monthly total to use as a standard. Having determined such a standard, it was merely necessary to compare the total man-hours for a given month as obtained from the Payroll Department in order to arrive at a percentage activity for the month. All that remained to do was to multiply the normal power consumption by the per cent activity to get the actual consumption for the month. This was done in the case of steam and current used for power, but that used for heating and lighting was assumed to be fixed irrespective of per cent activity, the former of course being included only during those months in which heating of the buildings was necessary.

It will readily be comprehended that the total of the horsepower-hours as determined by such a method as the foregoing, would never agree with the total of the electrical energy as recorded by the station instruments. Also that the pounds of steam would not total up to the same figure as the pounds of water evaporated. What really would have had to be done was to compare what may be called the theoretical totals with the actual totals and distribute the component theoretical parts in the ratio of the totals. As a matter of fact, it was not necessary to go through this step since the object in view was to get a division of the expense. Hence, by dividing the total power expense in the ratio of the theoretical components the desired result was obtained without going through the intermediate step. What was necessary, however, was to divide the total power cost into two parts, namely, the cost of the electrical and the cost of the straight steam part. The cost of the electrical part was the cost of the steam used in the turbines plus charges identified

with the generation of current only. Therefore to get at the two costs three things were required; the cost of generating steam (inclusive of that used for the electrical generation), the division of the steam into that part used by the mills and that used by the generators, and the cost of electrical generation. Then by dividing the total steam cost in the ratio of the straight steam and the generator consumption, the straight steam cost would be known, and by adding to the electrical steam cost the expenses of generation the total electrical cost would be known. Having the totals, it would remain to distribute them among the departments on the normal demand-per cent activity basis.

Amount of Steam Generated

While the scheme as outlined in the foregoing is simple enough in theory, it must be remembered that no means were at hand to determine the total steam generated, much less to measure that part of it used for electrical conversion. As a matter of fact, it became a problem of figuring back from the data available, namely the coal consumption and the electrical energy production. The approximate amount of water evaporated could be figured from the coal fired if the steaming efficiency of the boilers were known, and likewise the part of the steam used for electrical generation could be figured back from the kilowatt-hours generated if the efficiency of the generating units were known. Thus, if the evaporation was 6 lb. of water per pound of coal and 10,000,000 lb. had been fired during a month, it would mean that 60,000,000 lb. of water had been evaporated, which would indicate a steam consumption of that amount. Similarly if the turbines used 20 lb. of steam per kilowatt-hour and the electrical energy produced in the month was 500,000 kw.-hr., it would mean that 10,000,000 of the 60,000,000 lb. of steam were used for electrical power. As this appeared to be the only method by means of which any results could be obtained, it was necessary to run a test to get the efficiencies required. One of the boilers in average condition was selected for the purpose and a day's test was run on it, means having been provided to measure the feed water, and the coal being weighed as already described. By having the water in the column and the coal in the hopper at the same levels at the finish as at the start, it was felt that fairly reliable results had been obtained. The turbines operated on barometric condensers, and consequently no ready means were at hand to run a test on them. It was, therefore, decided to accept the manufacturer's guarantee as the basis of steam consumption, due allowance being made for the load factor. As the electrical load was after all only a comparatively small part of the entire power consumption, it was not thought profitable to elaborate on it, especially in view of the approximations that were necessary throughout the rest of the analysis.

Method of Obtaining and Applying Data

Having worked out a method and secured the means of obtaining the data necessary for it, there still remained the problem of applying the data to the method in order to get the results aimed at, namely, the power expense incurred by each of the departments every month. In order to have a clear view of the interrelations throughout the entire plant, a diagram such as that in Fig. 1 was prepared. For diagrammatic purposes, the electrical energy was represented as the combined flow of the direct and alternating current services since no attempt was made to determine separate rates for the two. It may also be stated here that the steam consumption of the engine units a and b, per kw.-hr., was considered to be the same as that of the turbine units c d and e, in order to avoid making the calculations more involved than they were already becoming.

To accompany the diagram, a table was constructed to show the original sources of information to be worked with, such as Table I herewith. The values corresponding to symbols A and B were obtained from the Accounting Department who required a statement of them in order to compute the coal costs C and D which entered into their records. Since the Accounting Department had to compute C and D it was unnecessary to repeat the operation and the values corresponding to these symbols were therefore obtained from that source. The total cost of water, represented by E, was also obtained from the Accounting Department, which got its information as to consumption from the Engineering Department. In spite of the fact that barometric condensers were used extensively throughout the plant, no well water was available, so that all water had to be bought.

TABLE II. MONTHLY MAN-HOURS OF VARIOUS DEPARTMENTS

Symbol Man-Hours	Dept.	Symbol Man-Hours	Dept.	Symbol Man-Hours	Dept.
a	A	e	E	i	I
b	B	f	F	j	J
c	C	g	G	k	K
d	D	h	H	l	L
				m	Misc.

Hence the total consumption and cost per month were readily obtainable, but of course not all of it was used by the power plants. There were, however, no submeters to tell what their use was, so the Engineering Department made what amounted to a good guess of the amount of the entire monthly bill which should be charged against power. The labor costs, F to K inclusive, were obtained from the Accounting Department, which gathered the information through its Pay Roll Department. As regards J and K, it should be stated that the two engine driven direct current generator units a and b were situated in the engine rooms of Departments C and G respectively, and the watch took care of their operation. Inasmuch as these units were operated only occasionally to help over some peak load, it was decided, as will appear further on, to charge all the labor J to Dept. C, and all labor K to Dept. G, rather than to remove part of it to charge to electrical power generation. Items L, M and N were naturally obtained from the Accounting Department; together they constitute the total indirect expense, whereas items C to K comprise the direct expense.

The information indicated in Table I was required monthly, to arrive at the actual costs for the month. This was also true of the data necessary to gage the per cent activity, which was therefore tabulated in a similar manner, as given in Table II. The values corresponding to a, b, c, etc., were obtained from the

Accounting Department through its Pay Roll Department.

Two other items were required before the monthly information was complete, namely, the amount of direct current and of alternating current energy generated. These are covered by Table III, and were secured from the chief engineer. The amount of alternating current energy supplied was derived from the watt-hour meter previously referred to, and indicated at h in Fig. 1. The only portion of the direct current energy which it was necessary to deal with was that supplied by the supplementary units a and b of Fig. 1 and that gen-

TABLE III. ELECTRICAL ENERGY GENERATED PER MONTH

Symbol Kw.-hrs.	Description
P	Alternating Current.
Q	Direct Current

erated on Sundays by the engine driven exciter set in the main station. That is, it was not necessary to consider the output of the motor-generator set i, since the alternating current required to furnish this direct current was included in the reading of meter h. The direct current outputs of a and b were computed from hourly entries of the readings of ammeters f and g in logs maintained for the purpose, assuming the voltage constant at 110 v. The output of the exciter set when used for outside generation was arrived at in the same way.

Before illustrating the use of the information contained in the foregoing tables it will be necessary to

TABLE IV. NORMAL FULL CAPACITIES OF VARIOUS DEPARTMENTS

Department	STEAM								CURRENT			
	Heating				Process				Lighting		Process	
	Battery #1		Battery #2		Battery #1		Battery #2					
	Sq Ft	Per Cent	Sq Ft	Per Cent	Lbs Steam	Per Cent	Lbs Steam	Per Cent	Kw-Hours	Per Cent	Hp-Hours	Per Cent
		Col 1		Col 2		Col 5		Col 4		Col 5		Col 6
A	---	---	(113)	95.4	---	---	(129)	96.4	(131)	15.3	(146)	31.7
B	(101)	29.4	---	---	(116)	50.7	---	---	(132)	20.0	(146)	14.6
C	(102)	None	---	---	(117)	30.6	---	---	(133)	2.5	(147)	None
D	(103)	0.5	---	---	(118)	0.3	---	---	(134)	9.2	(148)	21.0
E	(104)	5.8	---	---	(119)	1.3	---	---	(135)	4.2	(149)	4.3
F	(105)	5.5	---	---	(120)	4.4	---	---	(136)	5.0	(150)	16.4
G	(106)	15.2	---	---	(121)	16.5	---	---	(137)	5.8	(151)	2.8
H	(107)	3.1	---	---	(122)	5.8	---	---	(138)	5.0	(152)	2.1
I	---	---	(114)	4.6	---	---	(129)	3.6	(139)	5.3	(153)	1.4
J	(108)	1.8	---	---	(123)	0.3	---	---	(140)	5.3	(154)	1.9
K	(109)	10.6	---	---	(124)	0.1	---	---	(141)	7.6	(155)	2.1
L	(110)	5.5	---	---	(125)	None	---	---	(142)	0.8	(156)	0.6
Misc	(111)	23.5	---	---	(126)	None	---	---	(143)	20.1	(157)	1.1
Total	(112)	100.0	(115)	100.0	(127)	100.0	(130)	100.0	(144)	100.0	(158)	100.0

give the results of the surveys and analyses made to determine the normal full capacity loads and the normal monthly man-hours, as also the factors for working backward from coal and kilowatt-hours to weight of steam generated and weight of steam used for electrical generation. These factors are given in Tables IV, V and VI. The actual quantities are represented by symbols to make the method entirely general and to allow of changes due to subsequent variations. However, the relation between the quantities is expressed as a percentage. Thus, in Table IV the total radiation connected to Battery No. 1 is represented by the symbol (112) of which 29.4 per cent is in Dept. B, none in Dept. C, 0.5 per cent in Dept. D, and so on. Likewise the total connected radiation on Battery No. 2 is represented by (115). There are only two departments on this battery, namely A and I, of which A constitutes 95.4 per cent of the radiation and I only 4.6 per cent. The percentages in the other columns of Table IV express similar relations for their respective quantities.

Table V contains the normal capacity man-hours, and in addition has incorporated with it what are called "Normal Ratios." Here, as in Table IV, the actual man-hours over the representative past period are indicated by symbols, but the relations between them by percentages. Thus, of the departments served by Battery No. 1, Dept. B uses 18.8 per cent of the man-hours in the entire plant. That is,

$$\frac{(160)}{(172) - (159) - (167)} = 18.8 \text{ per cent.}$$

The quantities (159) and (167) are subtracted from the total (172) because these two are labor that uses steam from Battery No. 2 instead of Battery No. 1; as indicated in column 9 their total is divided in the ratio of 49.8 and 50.2 per cent. All the departments use current

TABLE V. NORMAL POWER DISTRIBUTION FACTORS

Dept.	Normal Labor				Normal Power Distribution			Normal Ratios		
	Man-Hours for Representative Period	Per Cent			Per Cent			3/8	4/9	6/10
		Steam		Current	Steam		Current			
		Battery #1	Battery #2	---	Battery #1	Battery #2	---			
		Col 8	Col 9	Col 10	Col 3	Col 4	Col 6	Col 11	Col 12	Col 13
A	(159)	---	49.8	14.3	---	96.4	51.7	---	1.936	2.217
B	(160)	18.8	---	13.4	50.7	---	14.6	2.697	---	1.090
C	(161)	3.5	---	2.5	30.6	---	None	5.886	---	None
D	(162)	9.4	---	6.7	0.3	---	21.0	0.032	---	3.134
E	(163)	8.4	---	6.0	1.3	---	4.3	0.155	---	0.717
F	(164)	12.0	---	8.6	4.4	---	16.4	0.367	---	1.907
G	(165)	7.4	---	5.2	16.5	---	2.8	2.230	---	0.538
H	(166)	4.0	---	2.8	5.8	---	2.1	1.450	---	0.750
I	(167)	---	50.2	14.4	---	3.6	1.4	---	0.072	0.097
J	(168)	20.7	---	14.9	0.3	---	1.9	0.014	---	0.128
K	(169)	10.8	---	7.7	0.1	---	2.1	0.009	---	0.273
L	(170)	3.1	---	2.2	None	---	0.6	None	---	0.273
Misc.	(171)	1.9	---	1.3	None	---	1.1	None	---	0.846
Total	(172)	100.0	100.0	100.0	100.0	100.0	100.0			

from the same source, hence the percentages in column 10 are based on the total (172). Thus, the current demand of Dept. A is 14.3 per cent, which is arrived at by dividing (172) into (159). The fact that the totals used for figuring the percentages in columns 8, 9 and 10 are (172) — (167), (159) + (167), and (172), respectively, accounts for the fact that the percentages in column 10 differ from those in 8 and 9, although they are all derived from the same values of man-hours. Columns 3, 4 and 6 are merely copies of the same

TABLE VI. EFFICIENCY AND CONSTANT LOAD FACTORS

Symbol	Unit	Description
n	Lbs.	Total steam required for heating load on Battery #1
p	Lbs.	Total steam required for heating load on Battery #2
q	Lbs.	Steam generated by one pound of coal
r	Lbs.	Steam required to generate one kw.-hr.
s	Kw.-hrs.	Electricity used for lighting

columns in Table IV and are included only as a matter of convenience in computing the factors in columns 11, 12 and 13. These contain the "normal ratios" which are obtained by dividing the values in column 3 by those in column 8, those in 4 by those in 9, and those in 6 by those in 10, as indicated at the head of 11, 12 and 13 respectively. In effect these factors give the normal power consumptions per normal man-hour. For example, choosing electrical power for Dept. A, it is found from Table IV that the normal horsepower-hours are

(145), and from Table V that the normal man-hours are (159); hence the power per man-hour would be (145) ÷ (159). For Dept. B it would be (146) ÷ (160), for Dept. C (147) ÷ (161), and so on. Using the percentages corresponding to (145), (159), etc., instead of the values themselves, will give a set of figures which bear the same ratios to one another as would the values, and which, therefore, serve equally well for the purposes of distributing the actual monthly power cost on the basis of the man-hours for the month. The normal ratio factors of columns 11, 12 and 13 are such a set of figures.

Table VI contains the efficiency and other factors determined by test or otherwise. As already stated, the heating load was considered to be constant throughout the winter months, irrespective of departmental activity. Likewise the lighting load was assumed independent of activity. Hence the factors n, p and s are constants so long as radiation and lighting remain unchanged. The factors a and r also will be constant provided steaming and generating practice remain unchanged.

The foregoing is a more or less general description of the methods employed in distributing the power charges in this plant. In a subsequent article the author will discuss in detail the means employed to apply the information contained in the various tables.

Combustion Engines

Types, Conditions for Efficiency, Methods of Governing

FUELS for combustion engines are mainly of two classes: gases, blast furnace, producer or natural; and liquids, chiefly oils heavier than kerosene.

Engines using gas or the lighter liquids run on the principle of mingling the fuel with air in proportions to form an explosive mixture which is ignited in the cylinder by a hot surface or electric spark, the latter being now almost universal. While there are variations in air required, best compression pressure and methods of producing the explosive mixture, the care and operation of engines using such mixtures is largely the same, regardless of the fuel used and all may be considered together.

In contrast are those engines using heavy oils and tars with specific gravity 26 deg. Beaumé or lower, in which the fuel is pumped into the combustion chamber, or blown in by air at high pressure, ignition being produced by compressing a charge of pure air to a high pressure and temperature, into which the stream of fuel is forced, burning as it enters, a sustained rapid combustion, in contrast to the instantaneous explosion of the type using a fuel mixture for the charge.

Contrasting the types, the explosive requires some form of ignition apparatus and can use but comparatively low compression pressures, 100 to 150 lb. at most, as higher compressions may result in preignition. In slow combustion engines, the compression will be from 450 to 500 lb., which gives a certain thermal advantage to the slow burning type. Maximum combustion pressure is, however, more nearly the same for the two types, since pressure rises during the explosion but does not increase much during the slow burning. Figure 1 shows comparative diagrams of the two methods of combustion for cylinders of the same total volume. Positions of events in the action are indicated, also clearance volume, which will be 15 to 25 per cent for the explosive diagram and about 8 per cent for the slow burning type.

For the slow burning (Diesel), air at high pressure, 700 to 1200 lb. per sq. in., must be provided, which involves a high-pressure air compressor, an apparatus as complicated as and rather more expensive than the ignition system of the explosive (Otto) type. For this reason, the Otto cycle is largely in use for gas and liquids which are readily atomized and mixed with air; but as the heavier fuels cannot be so atomized as to secure efficient combustion explosively the Diesel cycle is used for them, even to tars and experimentally for pulverized coal. The Diesel type has also shown better efficiency than the Otto type, partly because greater effort has been made to secure it on account of the higher price of the fuel used and the larger size of the powers involved in liquid fuel engines.

Two-Stroke and Four-Stroke Cycles

To secure high efficiency, it is essential that combustion take place at a high temperature, which involves high pressure. The charge must be taken into the cylinder and compressed before firing; also the burned

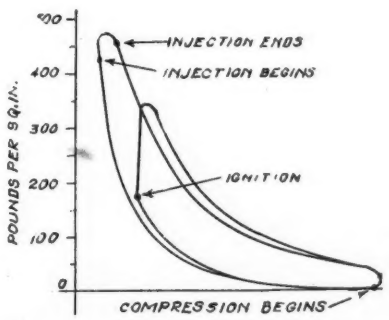


FIG. 1. COMPARISON OF EXPLOSIVE COMBUSTION (OTTO) DIAGRAM WITH SLOW BURNING (DIESEL) DIAGRAM

and expanded gases must be exhausted. For either Diesel or Otto principles, this may be done in either of two ways, the four-stroke or the two-stroke cycle, usually spoken of as four-cycle and two-cycle. In the former the piston on a forward stroke draws in a charge at atmospheric pressure, compresses it on the return stroke at the end of which combustion takes place, expands on the next forward stroke and exhausts on the succeeding return stroke. For the two-cycle, with the piston at the crank end of the stroke, the charge is admitted at low pressure, 4 to 7 lb. and blows out the burned gases; on the back stroke, the charge is compressed and at the end combustion takes place, this and expansion continuing on the forward stroke; near the end of the forward stroke exhaust ports are uncovered and most

of the burned gases allowed to escape, the rest being blown out by the incoming charge.

For the four-cycle, there is one power stroke in four, or in two revolutions; for the two-cycle, there is one power stroke in two or for each revolution. The latter would seem, therefore, to give twice the power for a given size of cylinder; but there is some loss from failure to get all the burned gases exhausted from the cylinder and from precompressing the charge, so that the two-cycle actually shows about 75 per cent more power than the four-cycle. Also the precompression necessitates added complication in the way of a compressor or in using the lower end of the piston for this purpose and it has been found that the two-cycle has somewhat higher fuel consumption than the four-cycle, so that the latter is usually preferred for small and medium sizes.

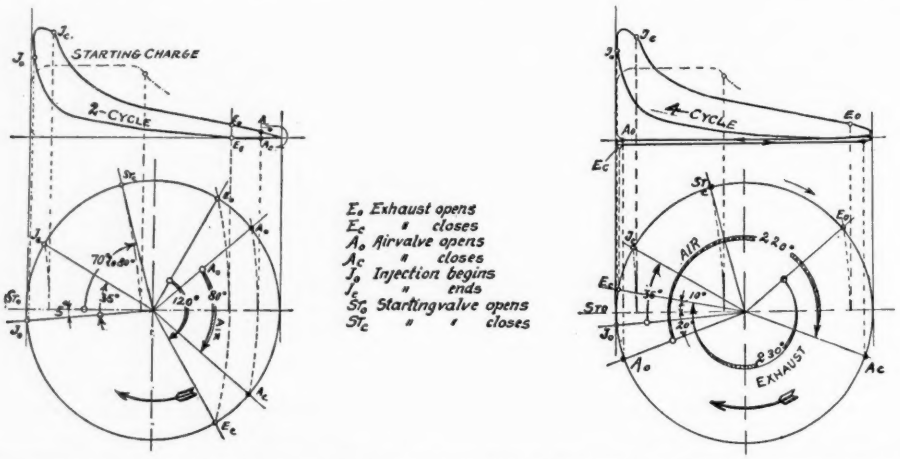


FIG. 2. TWO-CYCLE AND FOUR-CYCLE DIAGRAMS, SHOWING VALVE EVENTS AND CORRESPONDING CRANK POSITIONS

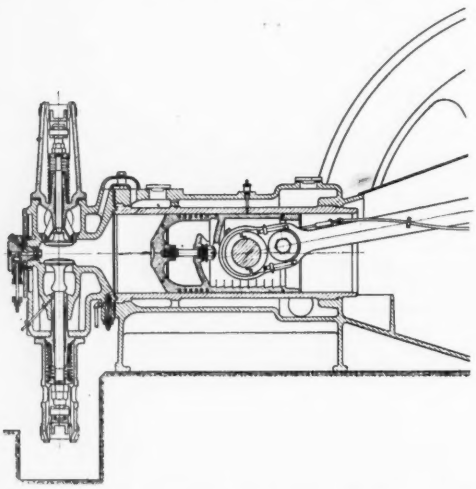


FIG. 3. SECTION OF ALLIS-CHALMERS HORIZONTAL DIESEL ENGINE CYLINDER

Diagrams for two-cycle and four-cycle Diesel engines are shown in Fig. 2 as given by Goldingham. Figure 3 is a section of a Diesel horizontal four-cycle Allis-Chalmers engine, the air inlet valve being on top, exhaust valve at the bottom and fuel injection nozzle at the left in the cylinder head. Figure 4 is a section of the Standard vertical two-cycle oil engine, showing the piston at the end of the down stroke with ports open at the left for exhaust and at the right for incoming air from the receiver at the right, into which it is compressed by the lower piston which also carries the wristpin.

Essentials for Good Combustion

Sufficient air to burn all the fuel, thorough mixture of the finely divided fuel with the air and temperature maintained until combustion is complete, are necessary for efficient performance. For the explosive type, this involves correct adjustment of the air and fuel inlets, effective atomization of liquid fuel, if used, and effective mixture of the air with fuel. In the slow-burning type,

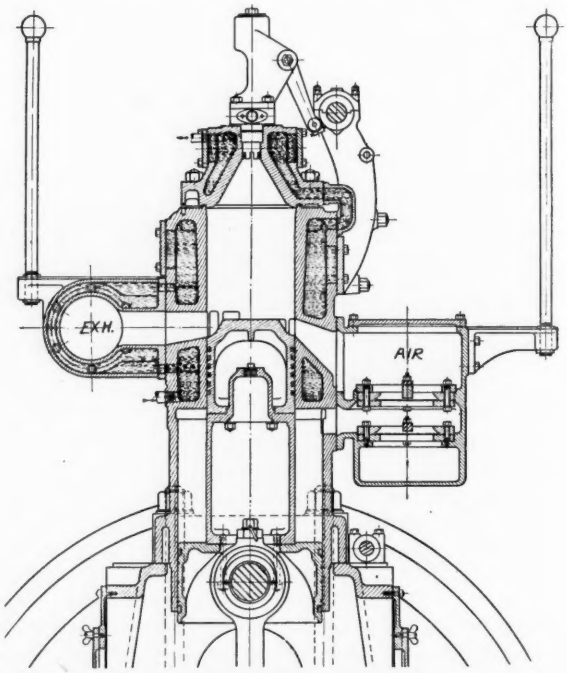


FIG. 4. "STANDARD" VERTICAL TWO-CYCLE ENGINE CYLINDER

since the fuel is injected into highly compressed air, it is necessary that the temperature be raised by compression well above ignition temperature of the fuel, which must be finely divided and widely diffused through the air by the injection force, but that the fuel be injected no faster than it can burn, unless there is a considerable surplus of air.

To raise the temperature in an Otto type engine, the compression should be carried as high as can be done without causing preignition. The most common causes of low compression are leaks past valves or pistons and shortening of the connecting rod by repeated taking up at the crankpin and wristpin bearings. Tests of the compression pressure should frequently be made by gage or indicator, cutting off ignition in the cylinder—or fuel supply in the case of Diesel engines—in the cylinder which is being tested, and noting the maximum pressure registered.

By improper adjustment of the carburetor or mixing valve, 30 per cent of the fuel may be wasted in a gasoline or kerosene engine.

Directions for carburetor adjustment are usually furnished by the engine builder, and vary with the details of the device; but in general, that adjustment which will give the maximum air supply without causing

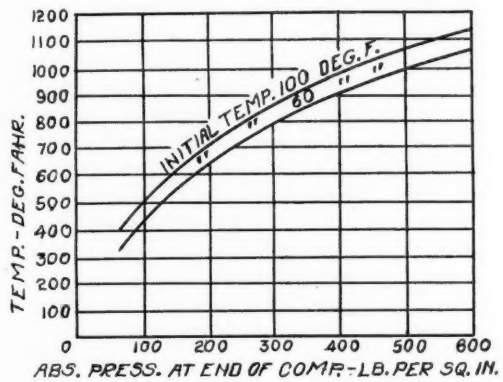


FIG. 5. RELATION BETWEEN COMPRESSION PRESSURE AND TEMPERATURE FOR INITIAL TEMPERATURES OF 60 AND 100 DEG.

misfiring as indicated by spitting back, will give the best fuel economy.

For the Diesel engine, low injection air pressure will cause smoky exhaust because the fuel will not be finely divided. The pressure needed will vary with the load and speed; but for the usual piston speeds—900 to 1000 ft. per min.—the pressure for injection air at half load or less should be 500 to 900 lb., above half load, 975 to 1050 lb. and for overload, 1125 lb.

Governing

For explosive engines, governing is usually either by throttling, Fig. 6, to reduce the quantity of fuel or of mixture admitted per stroke, or by the "hit and miss" method, in which the exhaust valve is held open when the engine gets above speed so that no fresh charge is taken into the cylinder, hence there is no explosion. The former method gives the smoother operation, as for each cycle there is a power impulse of greater or less force according to the charge. On the other hand, the latter method gives better fuel economy, as every charge taken in is compressed and fired under the same conditions, while the lowered compression pressure from throttling makes for lower thermal efficiency. As this effect is greater for low loads than for high, a combination is sometimes used, the hit and miss for the lower load range and throttling for the larger loads. For

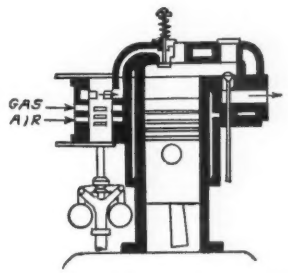


FIG. 6. PRINCIPLE OF THROTTLE GOVERNING BY GRIDIRON VALVE (HIRSHFELD AND ULBRICHT)

engines of 150 hp. and less the hit and miss is largely used for all loads, but for larger sizes it is not found desirable. Compression pressures and resulting temperatures as given by Megson and Jones are shown in Fig. 5.

Diesel engines are governed by regulating the amount of fuel delivered to each cylinder at each injection, either by controlling the time that the fuel valve is open, by holding open the suction valve of the fuel pump during more or less of the delivery stroke, Fig. 7,

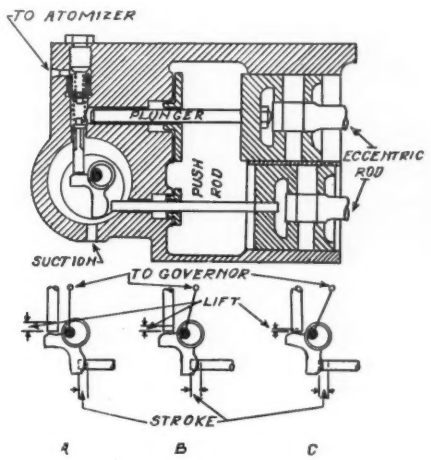


FIG. 7. GOVERNOR ACTION TO CONTROL FUEL CHARGE BY HOLDING OPEN SUCTION VALVE (MEGSON AND JONES)

or by varying the stroke of the fuel pump. Smooth operation requires that the same amount of fuel be delivered to each cylinder of a multicylinder engine, hence care must be taken that the governor acts alike on all fuel plungers, of which there should be one for each cylinder unless the fuel is supplied from a fuel header and the inlet controlled by the lift or time of opening of the fuel valves. In that case the governor should act alike on all fuel valves.

Novel English Turbo-Generator

WITH ALL STAGES OF NEARLY EQUAL DIAMETER, INTERMEDIATE BLEED-OFF FOR HEATING FEED WATER, AND DIVIDED MULTISTAGE EXHAUST END

IN THE power station of the Liverpool corporation system, has recently been installed a 12,500-kw. turbo-generator having several novel features which are described in an article in Engineering of London, England, from which the following facts are abstracted:

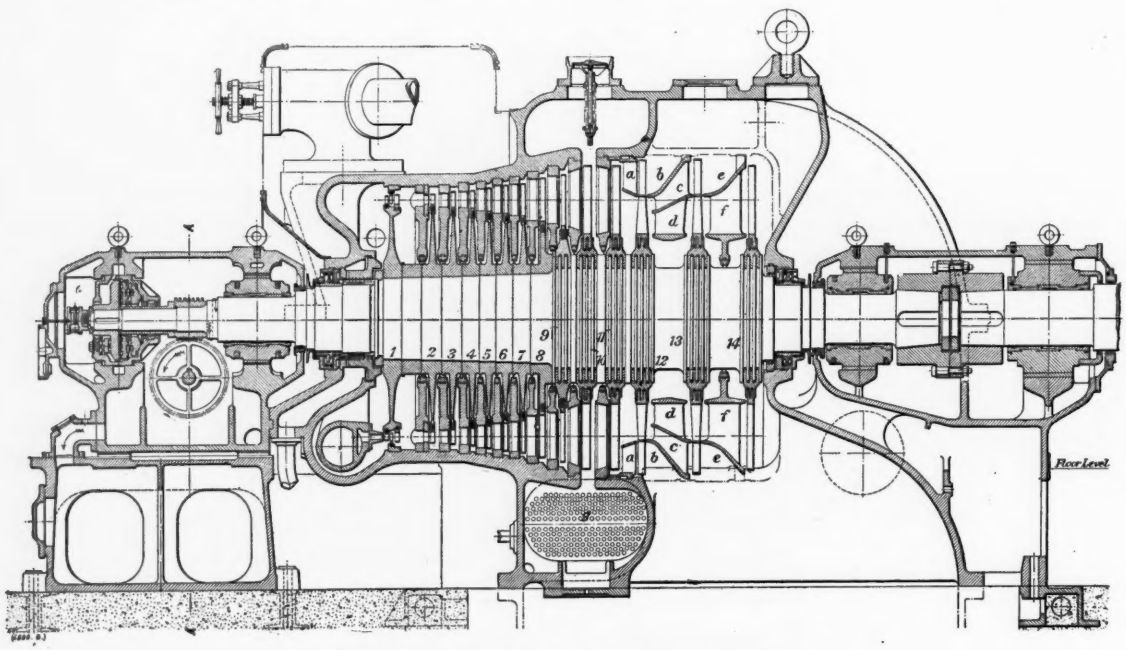
With pressure range from 185 lb. to 27.5 in. vacuum, and at 3000 r.p.m. the turbine has not so low a water rate as could be gotten with the conventional 29-in. vacuum; but the special design of the low-pressure end is expected to do away with the "throwaway" loss which is usually found in high-speed machines, so that the net economy will still be satisfactory.

As shown in the illustration, the arrangement consists of one compound velocity stage, followed by 10 Rateau reaction stages, extending to wheel 11 of the figure. Beyond this is a special multistage exhaust, wheels 12 to 14. All stages have the mean diameter 42 in. with the blades extending in toward the shaft in the lower stages, but the design of the low end gives a leaving area of 23 sq. ft. in place of 16 sq. ft. which would be given by the usual design.

Following wheel 10, part of the steam is drawn off to a heater g, having a surface of 650 sq. ft., which heats the condensate from 109 deg. up to 146 deg., the steam coming to the heater at about 19 in. vacuum. The water is further heated by steam coming off from the glands in a heater, not shown, having 88 sq. ft. surface, from which the water goes to the feed pumps. The condensate from the heaters goes to the main condenser.

Steam leaving the outer ends of the blades in wheel 11 passes through the nozzles a in which it is expanded down to condenser pressure and passes through the outer impulse ends of the blades on wheel 12 and to exhaust; the inner ends of these blades are proportioned as reaction blades, so that the steam passing through them has but little drop in either pressure or velocity, the outer third going to the nozzles C, where it is expanded so as to act on the outer impulse ends of the blades of wheel 13; the balance of the steam acts by reaction on the inner ends of the blades of wheel 13 and then is expanded through nozzles f to wheel 14.

Extending the low-pressure blades inward toward the shaft gives "wheels" which are little larger than the shaft and permits of exceptionally strong construction. Collars are turned on the shaft, and the insides of the wheels, which are made in halves, are also turned in collars which mesh with those on the shaft, the whole being riveted together.



LONGITUDINAL SECTION OF NOVEL STEAM TURBINE

At the low-pressure end, the steel casing is made of form that gives a strong bridge with clear area of 37 sq. ft., the turbine being bolted directly to the condenser. At the high-pressure end, the casing is carried by a tongue on the housing, turned concentric with the bearing and fitting into a groove in the casing which is concentric with the axis of the rotor. The weight is carried mainly by the side frames.

Placed directly beneath the turbine, the condenser has 7500 ¾-in. tubes giving a surface of 23,500 sq. ft. designed to care for 162,000 lb. of steam per hour, and to hold a vacuum of 27½ in. with cooling water at 84 deg. The leaving temperature of the water in normal service is 101 deg., the ratio of water to steam being 37 to 1. Diameter of the steel shell is 9 ft. 9 in. and length between tube plates 16 ft. The total weight is 50 tons. Cooling water is supplied by a 24-in. centrifugal pump which has a motor mounted on either end of the shaft,

one for regular use, and the other a standby, each of 500 hp. This pump works against 69 ft. head and the condensate pumps against 58 ft. The latter are two in number, 6 in. diam. running at 1440 r.p.m. and driven by 30-hp. motors. Air is drawn off by double-nozzle steam ejectors.

The generator has a normal output of 12,500 kw. at 80 per cent power factor, supplying 3-phase currents at 50 cycles per second and 6600 v., but overload of 25 per cent can be carried for 2 hr. It is cooled by a flow of 50,000 cu. ft. of air per minute, half being furnished by fans on the generator and the rest by a motor-driven fan 38½ in. diam. running at 960 r.p.m. and absorbing 80 hp. against 10 in. water gage. Air is cooled by a washer using 183 gal. per min., so that the temperature on reaching the generator shall not be over 80 deg.

Nozzle rings for supplying steam to the first velocity stage are three in number, covering about three-fourths of the circumference of the wheel, thus cutting down the fan action loss. Admission of steam to these rings is under control of the governor, which actuates the valves so that the rings come into action in succession, the first being active up to half load, the second being added to carry to full load, and the third to take overload.

How Much Coal Should Be Stored?

WITH ANOTHER coal strike impending, which is predicted for the end of March, it may be well to investigate briefly the conditions that have attended such strikes in the past with the view of ascertaining the effect they have had on the available reserve coal supply of the country, and, from this, the effect that the next strike may have. With this information at hand, the consumer may judge what amount of coal he should be prepared to store against the time when a shutdown might otherwise be inevitable on account of lack of fuel.

Reviewing the statistics published by the Department of Commerce and by the United States Geological Survey, Department of the Interior, we are enabled to single out some interesting facts.

Since 1902, there have been five coal strikes of major importance:

Year	Men on strike	Days lost per man striking
1902	200,452	83
1906	372,343	52
1910	218,493	88
1912	311,056	40
1919	446,436	35

When it is considered that the average output of a miner per day is in the neighborhood of 3.75 T., it will be seen that the lost production amounted to about 62.5 million tons in 1902, 72 million tons in 1906 and 1910, 47 million in 1912 and 58.5 million in 1919. The estimated commercial stocks on hand Jan. 1, 1919, were 57,900,000 T., and on April 1, 40,400,000 T., showing that the quantity was insufficient to tide over the strike period.

Stocks of coal are significant because they are the consumer's reserve against a possible interruption in supply. Such interruptions have occurred in the past through mine strikes, traffic congestion on the railroads, or severe weather interfering with the delivery of loaded coal.

Consumers' stocks of bituminous coal on Nov. 1, 1919, were approximately 47 million tons which was 25 per cent below the maximum of 63 million tons reached during the war.

At the present comparatively low rate of consumption, the present stocks would probably last about 43 days if evenly divided among the consumers. With business active these stocks would last only about 35 days. By the low rate of consumption is meant about 1,100,000 T. a day. The active rate probably reaches 1,350,000 T. a day.

Stocks, however, are never evenly divided; in every community there are consumers who carry virtually no reserve, and therefore, as experience has shown, symptoms of a shortage develop in a surprisingly short time if for any reason the delivery is stopped.

The present stocks are about the same as those on Jan. 1, 1921, or about 49 million tons. During the spring and summer, stocks declined to about 39 million tons, but increased rapidly in the fall due to the fear of a possible railroad strike. Since then, production has fallen off materially and now is less than the consumption so that coal is being withdrawn from storage.

The best index to changes in stocks is furnished by the class of general industrial consumers. In terms of days' supply, the stocks of industrials on Nov. 1, 1921, appear large on account of the present low rate of consumption. The apparent supply for three industrials; by-product coke plants, steel plants, and other miscellaneous industrials; at this date, Nov. 1, 1921, figured on the rate of consumption at that time, averages 50 days.

That which constitutes a safe reserve varies with the distance of the plant from the mine and the character of the coal. In response to these influences, consumers in some localities habitually carry heavier stocks than do those in other localities. Regions of relatively heavy stocks are in general a long distance from the mines. Plants in those states producing coal in quantity carry smaller stocks.

Public utilities as a class were in a relatively strong position on Nov. 1. The electric utilities had on hand an average of 54 days supply as compared with 44 days on Aug. 1. The sharp increase was due, probably, in large part to the threatening railroad strike.

The production of bituminous coal during the year 1921 totaled 407,000,000 net tons or an average of 1,326,000 T. per working day (307 working days) which is much below the average of the pre-war years, 1913-1916. The production in 1919, while less than war-time production, was greater than the pre-war years. Due to the strike in that year, the daily output fell from a maximum of 2,100,000 T. in October to a minimum of only 800,000 T. in November. During the last year the maximum output was reached in October, 1,700,000 T. per day. Since that time, it has dropped off steadily to 1,200,000 T. per day in December. At this time the production was below the consumption, but since then, during the first weeks of January, there has been a marked increase.

An average of all mines making weekly reports to the U. S. Geological Survey shows that the percentage of full time output produced in the United States was

something less than 40 per cent for the week ending Dec. 31, 1921, as compared to 67 per cent Jan. 1.

This would indicate that the present reserve is less than it was a year ago, but it does not necessarily indicate that the supply would last for a shorter time, owing to the fact that the present consumption is less than it was last year at this time.

The question is: How much coal should a given plant keep in storage as a guarantee against a shutdown in case the supply is curtailed? The problem is one that cannot be decided in a general way for all classes of plants or even for all plants in a given class. It is one that must be decided separately for every installation. It behooves every consumer then to look into this question and find out if he is adequately prepared for any emergency that might arise.

Notes on British Power Plant Practice

EXPERIMENTS WITH WOOD FUELS, STANDARDIZED BOILER EQUIPMENT, COMBUSTION INDICATOR, PEAT FUEL IN BRITISH PLANTS. BY C. H. S. TUPHOLME

THE possibility of utilizing wood as fuel on a large scale has lately been considered by several British plants, largely on account of the prevailing high prices of coal. It has been found, as a general rule, that about five volumes of wood are required to give the same calorific value as one volume of coal, so that a greater depth of wood on the furnace bed is required, sometimes as much as four times the depth of coal bed. At one plant I visited recently, the manager had purchased a stock of creosoted railroad sleepers and was utilizing them to generate steam in two boilers.

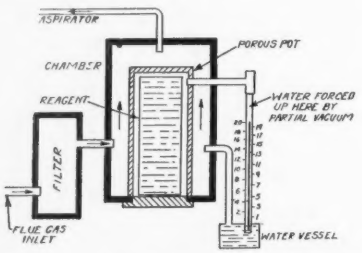


FIG. 1. BRITISH TYPE OF COMBUSTION INDICATOR

When first these were tried, they were sawed in halves and fed into a furnace which had been lighted with coal. When the fire bed was all wood, it was found that about a 35-in. thickness of these half sleepers was required to give the same evaporation as coal had previously done. While I was there, these half-sleepers were sawed up again into quarters, with the result that a bed of approximately 28 to 30-in. thickness gave the same evaporation.

These smaller blocks burned better, partly, I considered, on account of the better draft, and partly because the thicker fire-bed gave longer flames which were somewhat dampened on coming into contact with the relatively cold heating surfaces.

The smaller blocks were easily handled and were thrown in by hand.

I had five samples taken of these sleepers and they showed, on an average, 81 per cent volatile content.

Several other plants, mostly wood-working, have overcome the long-flame difficulty by increasing the depth of their furnaces with good results, the amount by which these furnaces have been deepened depending chiefly on the average length of the wood blocks utilized. If the blocks can be obtained about 10 in. or 1 ft. in length, no alteration has been found necessary, provided the wood is fairly dry.

On the other hand, where a regular source of supply has been available, it has been found more economical, in the case of the smaller plants, to carry out alterations to the furnace instead of having the logs sawed up smaller. This is particularly the case where the wood has a tendency to dampness.

One plant in particular was obtaining good results. Here the grate had been lowered, but still maintained horizontal as a small quantity of coal dust was burned with the wood. At first, the grate had been raised at the back of the furnace, but it was found that the addition of the coal dust (several tons of which were on hand) made little difference to the heating efficiency of the wood. When the whole grate was lowered horizontally, however, an appreciable improvement was registered.

Another plant, equipped with a single boiler, with an external furnace, was trying wood instead of coal but got no results worth speaking of. Several expedients were tried, such as lowering the furnace doors, but little improvement was manifest. Finally, the foreman in charge of the plant and myself set about studying the problem. First of all, we put the grate just about as low as it would go and tried that; some slight improvement showed. Then we split up the wood smaller, i. e., into about 6-in. squares, and dried it under cover in a glass outhouse. The damper puzzled us a good deal, but we analyzed the gases and found that the damper could be maintained at about the same opening as for coal; previously we had it "in" too much.

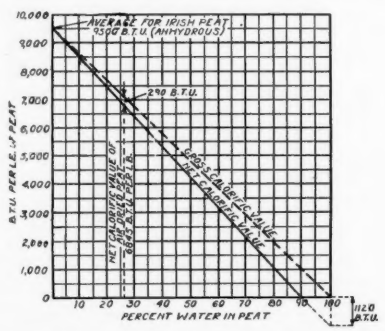


FIG. 2. CHART SHOWING VARIATION IN CALORIFIC VALUE OF PEAT WITH VARYING AMOUNTS OF MOISTURE CONTENT

With these changes it was found that a bed of wood four times the thickness of the coal previously used gave about 75 per cent of the evaporation afforded by coal before the conversion.

From these results, and others on the same lines, it is really worth while for those plants in the neighbor-

hood of cheap wood supplies to consider seriously whether it is worth while making the change over from coal to wood.

Standardizing Boiler Equipment

Standardization is being adopted widely in British power plants, especially in boiler design, boiler furnaces, gas outlets and external flues. To assist power users in the standardization of their equipment, W. H. Casmey, of Holdsworth & Sons, Ltd., boiler manufacturers, gives the following data:

"The depth of the bottom flue of any diameter of boiler should be half the diameter of that boiler, and the width equal to half the diameter plus 6 in. The side flues should be one-seventh the boiler diameter. The distance from the back end of the boiler to the face of the brickwork forming the downtake should be equal to the diameter of one furnace flue front end. The distance from the top of the bridge to the corner of the flue should be one-third the diameter of the flue. The walls of division between boilers should be 16 in. thick, including a 2-in. space in the center filled with flue dust. All external walls ought to be equipped with similar dust spaces, which will materially aid in reducing heat losses through the brickwork to the minimum.

"For instance, take a boiler 30 ft. long by 9 ft. in diameter, with modified grates, 35 sq. ft. outlet from furnace flues being 17½ ft. square; with 3 sq. ft. at this point requiring 1 sq. ft. of chimney area. In this case, the sectional area of the chimney would be 6 sq. ft., say 2 ft. 9 in. in diameter.

"To determine stack height for a given coal consumption, say 900 lb. of coal per hour, I have found it answers very well to divide this figure by 10, giving the required stack height of 90 ft., 100 ft. for 1000 lb. per hr., and 150 ft. for 1500 lb. per hr."

Economizers More Popular in Britain

The prevailing high cost of steam production in Britain is driving more power plant engineers to install the various devices to insure economical combustion. One of these devices is the economizer in its various forms. For the main, these economizers are employed to heat the feed water to the boiler by means of the heat from the exhaust gases, the water being pumped through tubes into the economizers, which are surrounded by the hot furnace gases on their way to the chimney stack. Such a type of economizer is popular chiefly in power generating stations, since a reserve of hot water can be stored in the economizer to provide against the peak load hours. Naturally the life of the boilers in such an installation is appreciably lengthened, since there is no sudden contraction arising from the injection of cold water.

A British Type Combustion Indicator

A useful instrument which is being adopted by many British plants is one which indicates, instead of records, the percentage of carbon dioxide in the gases. In this instrument, an aspirator, operated by the stack draft, draws in gas from any flue to which it is connected. The action of this aspirator draws the gas first of all through a filter into a porous pot filled with some dry reagent. The chamber which contains this porous pot is connected with a vessel containing water, into which dips one end of a pipe, the other end of which is taken into the porous pot. In operation, some of the gases penetrate into the interior of the pot, and some are absorbed by the reagent. The result of this is the formation of a partial vacuum which draws water up the indicating pipe, so graduated that the percentage of carbon dioxide is indicated at once. The principle of the apparatus is shown in Fig. 1. Where forced draft is employed, the aspirator is dispensed with.

Peat Fuel in British Power Plants

When considering the utilization of peat for power production, according to Professor Pierce F. Purcell, A. M. Inst. C. E., to the Royal Dublin Society, there are two main lines of procedure open to us. The first is to burn the peat with its fixed carbon volatiles to complete oxidation in a water tube or other form of steam boiler and then use the steam thus produced in a turbo-generator for the production of electrical energy. The second alternative is to consume the peat in a gas producer, the peat being partly oxidized with the production from each ton of peat used of some 60,000 to 80,000 cu. ft. of a power gas of a low caloric value—say, 100

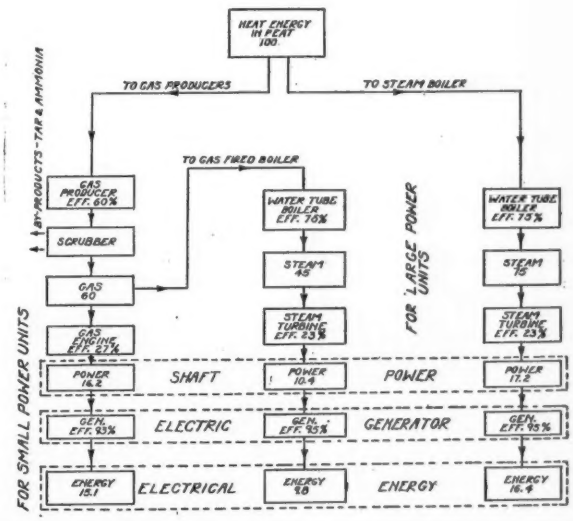


FIG. 3. POSSIBLE WAYS OF UTILIZING HEAT UNITS IN FUEL

to 150 B.t.u. per cubic foot—the power gas produced being used in a gas engine or in a gas-fired steam boiler and the steam used in a turbo-generator.

Several leading manufacturers of gas producer plants have claimed that they have been successful in using peat containing 60 to 70 per cent moisture, whereas to burn peat in a steam boiler furnace, the moisture content ought not to exceed 30 to 35 per cent. Since steam has to be supplied to the producer when using a dry fuel, it would naturally be a great advantage if the moisture required could be supplied by the peat, thereby avoiding the necessity of drying the peat to so great an extent.

Figure 3 shows the possible ways of utilizing the energy in peat fuel. To do this, certain efficiencies have been assumed for each stage, at which one form of energy has been converted into another.

In the steam boiler division, about 75 per cent of the heat units in the peat are available for the production of steam by burning the peat in a water-tube boiler; and these 75 steam units, when used in a modern steam turbine, with a thermal efficiency of. 23 per cent, will give 17.25 units of shaft power, which in turn yield 16.4 units as electrical energy.

Taking the other division, the 100 units put through a gas producer with 60 to 70 per cent thermal efficiency, will give, say, 60 units of energy contained in the gas if the by-products are recovered.

Two alternative methods are here open for the utilization of the gas. It may be burned in a gas-fired boiler, and the resulting steam employed in a turbo-generator. A thermal efficiency of 75 to 80 per cent with gas-fired boilers is said to be attainable, but it will be seen that one extra operation must be introduced, so that two operations are necessary to convert the heat energy of the peat into steam, as compared with one in the peat-fired steam boiler. This involves further loss of energy, and in addition, increased capital charges must be borne, so that unless the profits on the by-product recovery plant are of sufficient value, this system cannot compete with the direct peat-fired steam boiler. The energy produced by this system is:

$100 \times 0.6 \times 0.75 \times 0.23 \times 0.95 = 9.8$ per cent of that put in.

The second alternative is to utilize the power gas from the producer in a gas engine which in turn operates a generator. This method offers fairly high efficiencies, but it is doubtful whether it can be employed on a large scale, as it is said that serious mechanical difficulties are experienced in the working of large gas engines of 500 hp. and upwards, and that 300 hp. appears to be a useful limit. For such powers as 300 hp., this method gives good results. About 16 per cent of the heat energy put in appears as shaft power, and the electrical energy is derived thus:

$100 \times 0.6 \times 0.27 \times 0.23 = 15.1$ per cent.

To arrive at a sound conclusion as to the best method to adopt for the utilization of peat fuel, we must take into account not only the overall efficiency of the processes involved, but also the labor, depreciation, maintenance and capital charges. We must further take account of the profits from the by-products obtained when peat is gasified in a producer, and this involves the estimation of the cost of production of the by-products, with the labor, maintenance, capital and amortization charges on the recovery plant.

We must remember that the process of gasification in a producer can be varied within wide limits, and the working of the system and its thermal efficiency depends on the end in view, whether it be the maximum production of by-products or the maximum production of power gas.

Figure 2 shows the calorific value of peat compared with the percentage of water present.

Rapid Analysis of Power Plant Records

GRAPHIC METHOD AUTOMATICALLY CHECKS UP THE CORRECTNESS OF OPERATING CONDITIONS. BY W. J. BITTERLICK

TWO monthly reports, Fig. 1 and Fig. 2, show the same power plant records of a manufacturing plant. The busy plant engineer, when handed a report such as is shown in Fig. 1, is obliged to study and analyze some time before he is assured of its correctness or whether any unusual condition occurred in the operation of the power plant.

By plotting a graph, Fig. 2, of the same figures, he can see at a glance any unusual condition. For instance, the coal, water and horsepower curves should follow the same contour, therefore requiring but little study to determine whether they are correct or not.

The curves automatically check the numerical figures and Sunday and holiday reduced loads are quite evident as may be seen.

Other records, such as metered steam, water, air, gas,

FIG. 1. POWER REPORT FOR MONTH OF JANUARY, 1920

Day	Lbs. Coal	Outside Temp.	Lbs. Water	Water Temp.	B. H. P.	Flue Gas Temp.	A.C.	D.C.	Co.2	Actual Evap.	Equiv. Evap.	Factor Evap.
1	220580	34	2314000	194	71466	390	67500	3600	10	10.49	11.18	1.0655
2	261315	18	2574000	182	80421	405	70000	3600	12	9.85	10.62	1.0779
3	257235	18	2628000	182	82108	400	68750	3600	13	10.10	11.01	1.0779
4	192535	14	2160000	194	66710	375	9250	200	12	11.22	11.95	1.0655
5	248750	18	2552000	182	79734	380	69250	6300	12.5	10.26	11.06	1.0779
6	222995	31	2348000	191	72727	370	69000	7000	13	10.53	11.25	1.0686
7	209665	42	2320000	194	71651	410	66500	6900	14	11.06	11.80	1.0555
8	206685	41	2278000	197	70085	400	69250	6800	13	11.02	11.70	1.0624
9	227605	29	2386000	206	72832	400	68350	7000	13	10.48	11.04	1.0531
10	231960	24	2496000	209	75965	425	67250	6700	14	10.75	11.30	1.0500
11	170595	30	1820000	200	55882	375	9250	1170	13	10.68	11.30	1.0593
12	261300	23	2520000	206	76922	425	68000	3700	11	10.00	10.56	1.0551
13	239975	23	2520000	209	76696	440	69500	3600	12	10.50	11.03	1.0500
14	262000	16	2600000	203	79600	425	67500	3600	12	9.92	10.48	1.0562
15	250505	7	2572000	200	78974	450	70750	3600	11	10.27	10.87	1.0593
16	259745	15	2628000	200	80691	430	70250	3600	12	10.12	10.71	1.0593
17	238840	24	2394000	200	73506	430	68250	3600	14	10.46	11.08	1.0593
18	219223	12	2114000	203	65719	440	9600	300	13	9.64	10.19	1.0562
19	267660	17	2736000	200	83700	450	70250	7300	13	10.18	10.80	1.0593
20	258505	15	2614000	203	80026	450	69500	7200	13.5	10.11	10.68	1.0582
21	244695	23	2646000	206	80826	450	71250	7100	13.5	10.86	11.40	1.0531
22	244530	25	2630000	203	80310	460	70250	7400	12	10.31	10.88	1.0562
23	259065	31	2496000	209	75965	440	69500	7100	12	10.44	10.96	1.0500
24	253162	19	2400000	206	73260	450	66750	7400	12	10.39	10.84	1.0531
25	195830	13	2000000	209	60870	430	9000	300	10	10.21	10.72	1.0500
26	261635	15	2566000	200	78788	460	70000	4100	12	9.81	10.39	1.0593
27	243520	19	2542000	200	71910	450	69250	3800	13.5	9.62	10.18	1.0593
28	243680	25	2436000	209	74140	450	69750	3600	12	10.00	10.50	1.0500
29	242380	41	2436000	209	74140	450	71000	4000	12	10.05	10.55	1.0500
30	237575	22	2458000	200	75471	450	69500	6500	12.5	10.34	10.96	1.0593
31	254925	3	2654000	200	81489	460	67000	7000	12	10.41	11.00	1.0593
Totals	7328470 3664 Tons	22 Aver	75518000	200 Aver	2321486	426 Aver.	1905000	147570	12.35 Aver.	10.32 Aver.	10.93 Aver.	1.0591

power factors, etc., may be plotted in this same manner, thus making them easy to analyze. The most important graph is the cost chart and by comparing it with the production records will show interesting results that will keep the chief operating engineer always on the alert for economy of operation.

To prove effective, the curves should be plotted daily from daily records and should any unusual operating condition occur, it can be corrected immediately with a minimum loss or wastage of power. The writer has used this system for several years with gratifying results.

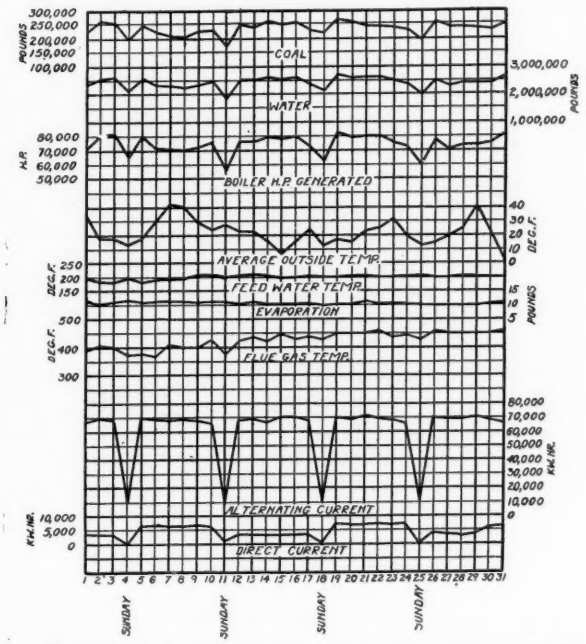


FIG. 2. POWER GRAPH CORRESPONDING TO REPORT SHOWN IN FIG. 1

Just a word of explanation for the excellent evaporation records shown; two of the six 500-hp. boilers had rubbish burners built low down and on sides of the boiler settings, the flue of which connected with the last pass of the boiler. These burners were kept busy all day and the heat from them, which was free of charge excepting for labor in loading, was a direct gain for the boilers.

Treatment for Carbon Monoxide Poisoning

IN SPITE of the common occurrence of carbon monoxide poisoning there appears to be no uniformly recognized treatment for a person overcome by carbon monoxide. In the rescue work of the United States Bureau of Mines, however, a method has been developed which has been supported by laboratory investigation and has proved successful in practical experience over a period of years.

The first and most important thing in caring for a case of acute carbon monoxide poisoning is to get the poison out of the blood. Every moment that it shuts the oxygen out of the hemoglobin adds to the chances of respiration and failure of the heart. Every minute that the tissues are supplied with only a part of the oxygen they need increases the danger of their degeneration and permanent damage. Both to save life itself and to prevent ill health in the future, it is of vital importance to eliminate carbon monoxide from the blood as rapidly as possible.

The first step is to get the victim away from the atmosphere of carbon monoxide which he is breathing; the next is to supply him with oxygen. This may be done by getting the patient into fresh air, but only one-fifth of air is oxygen. If a tank of pure oxygen is available, it is far better to use it, as the action is much faster and the after-effects, especially the headache, are much less severe and not so prolonged.

In view of the great importance of administering oxygen to these victims at the earliest possible moment, it is recommended that all ambulances be equipped with oxygen tanks. It may be that when the victim is found his breathing has stopped or is very weak and irregular. In this case, after quickly removing the victim to good air, or while administering oxygen, one of the rescuers should begin at once artificial respiration by the Schaefer method.

Continue artificial respiration, if necessary, for at least 3 hr. without interruption, or until natural breathing has been restored or a physician has arrived. Even after natural breathing begins, carefully watch that it continues. If it stops, start artificial respiration again.

While the administration of oxygen is by far the most important factor in the treatment and cannot be over-emphasized, other things should be done to help the patient. He should be kept quiet and lying flat, to help his weakened heart. When he revives he should not be allowed to walk about or in any way exert himself, for there is danger of heart failure. Heat from safety lamps, hot-water bottles, or warm bricks, rubbing the arms and legs, and keeping the patient well covered with blankets all help the circulation and aid in tiding the body over a period of low vitality. The safety lamps, hot bricks, etc., should be well wrapped in cloth or paper as a precaution against burning the patient. Other stimulants, such as hypodermics of caffein-sodium benzoate or camphor in oil, should not be administered except by a doctor, after he has considered the possibility of over-stimulation and consequent collapse. The patient should be kept in bed for a day at least.

Complete details of methods employed in the treatment of carbon monoxide poisoning, including a description of the Schaefer method of artificial respiration, are given in a report which may be obtained by applying to the Bureau of Mines, Washington, D. C.

Correction Note

AN ERROR has been brought to our attention in connection with the article "Flywheels" by Gordon Fox which appeared in the Nov. 15 issue of Power Plant Engineering. A formula is given as follows:

$$\text{Radius of gyration} = \frac{R_1^2 - R_2^2}{2}$$

This should read as follows:

$$\sqrt{\frac{R_1^2 + R_2^2}{2}}$$

Bonehead Engineering

By W. F. Schaphorst*

MISTAKES are made by the best of engineers. A man may not be ridiculed simply because he errs. The Quebec bridge fell into the water twice. Each time it was designed by and was being erected by high salaried engineers of much experience. The third time it did *not* fall into the river. James Watt, it is said, made some mistakes. Rudolph Diesel himself confessed before the American Society of Mechanical Engineers that he was nearly killed while experimenting with his engine. All of us make mistakes and after they are made we very likely consider them "bonehead" mistakes.

A first-class erector of machinery told me one on himself the other day. He said that some years ago he wanted to make a pipe coil. He espied a telephone pole out in the yard and this pole suggested to him this brilliant idea: Why not do the bending around the telephone pole? He did it. It worked fine. It did not occur to him until the job was finished that a coil of that kind is removed with great difficulty. He removed it by "unbending" the pipe. Next time he used a short post.

Recently a consulting engineer, drawing a salary that is in the five figures, made a sketch for a large metal tank to be used in a certain building. Drawings were made and specifications were written in accordance with the consultant's directions. The consultant wrote his O. K. on the tracings with a perfectly self-satisfied air. The tank was made. It was a beautiful piece of work. But, it was so large it wouldn't begin to go into the building. It was necessary to unrivet the tank, enter it into the building piece by piece and do the riveting all over again.

A man who unblushingly calls himself an engineer repaired (?) a globe valve a few days ago by inserting a new disc. He didn't remove the old disc, but put the new disc in on top of the old one. He said to me, "I can't understand why that valve still leaks. I just put in a new disc this morning."

Another engineer had trouble with the inertia governor on the high-speed engine he was operating. The governor "hunted too much" to suit the engineer. Being a believer in always carrying plenty of baling wire in stock he fixed it by wiring the governor to one of the arms of the flywheel. He then governed the engine himself by simply manipulating the throttle. It worked much better. He was proud of and boasted about his achievement, until, one day, the belt broke, the engine of course raced, and centrifugal force disrupted the flywheel. Nobody was killed. Nobody was hurt. The engineer wasn't even fired.

A large ice tank was assembled, riveted and calked about 4 ft. above the cork insulation on which it was to rest when in its final position. The owner demanded that a tightness test be performed with the tank under a full head of water. The contractor protested, saying that it could not be done without ruining the cork or without placing so many braces beneath the tank as to make the cost of bracing prohibitive. The problem was to distribute the load over the cork on an area sufficient so that the cork would not be compressed or mutilated in any way. The writer suggested without giving the problem much thought that the ice cans be placed in the tank so as to displace as much water as possible, thereby "lightening" the tank to the extent of the volume of water displaced.

The foreman to whom I spoke seemed to think it was a good idea and I thought I had made a first class suggestion, but on the way home on the trolley car the thought came to me: "How am I going to hold the ice cans down to the bottom of the tank without making the cans heavier or without ballast?"

The foregoing is somewhat similar to the story related by an engineer of an irrigation project in Arizona. An irrigation flume had been built which carried about as much water as an average canal. One of the residents decided that he could make double use of the water by running a boat in it; however, he was told that the flume was not built for any such purpose—that it was not strong enough to hold "heavy concentrated loads."

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Electrical Exports in 1922

OPTIMISM over the prospects for American exports of electrical equipment this year is expressed by E. D. Kilburn, vice president and general manager of the Westinghouse Electric International Co., who, through his dealings in export trade, is recognized as an authority on electrical export trade.

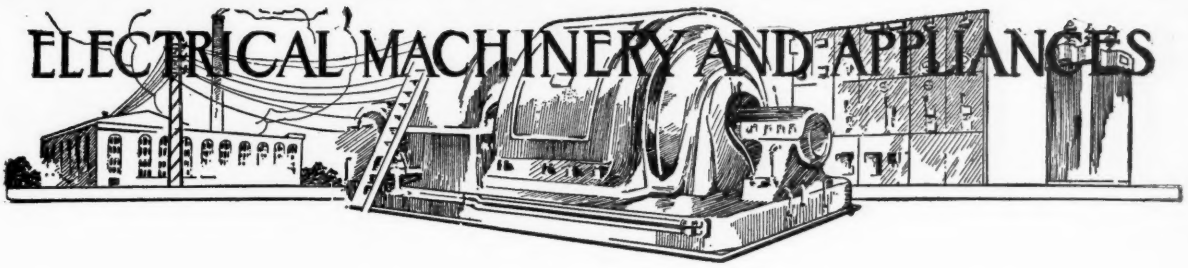
Mr. Kilburn declares, in an interview, that European, and especially German, competition in the electrical field "cannot seriously affect America."

"The past year both Chile and Japan placed large orders for electrical material in America and there is every reason to believe that we will receive an increasing amount of business of the same character. Every generator installed immediately creates a market for at least three times its capacity in smaller apparatus, such as transformers, meters, industrial motors and domestic ware.

"Though Germany is able to underbid us in some other lines, her manufacturing capacity is strictly limited and after she obtains a certain amount of business her deliveries will become uncertain and her prices will rise to a point that more nearly corresponds to our own.

"There is, however, a problem that still faces the exporter. Unless the American public, led by American financiers, becomes interested in investing money in foreign securities, American exporters are bound to be handicapped. Many European countries habitually buy large amounts of such securities each year and the money thus raised is naturally spent in the country of its origin. We have made great strides in this direction as the numerous foreign loans floated here testify, but there is still ample room for constructive educational work on the part of bankers along these lines."

An examination of the peat bogs of Wisconsin has recently been made by engineers of the Bureau of Mines with the object of defining their relation to the formation of coal.



Synchronous Motor Starting Torque Characteristics

A New Testing Method Which Will Procure the Necessary Data and Which Is Free From Disadvantages of Older Methods. By O. E. Shirley

THE USE of synchronous motors has been extended to a great many new applications during the past few years, and in a number of these cases the starting-torque requirements are quite severe. In some applications the starting requirements are heavy while the remainder of the cycle is comparatively light, and in others the starting torque may be low but that required at the higher speeds is quite high. These different requirements make it necessary that the designer know the shape of the required torque curve, as well as the actual values, if a properly designed starting winding is to be obtained.

TABLE I. STARTING TEST DATA

Voltage Held at 1560 Volts = 24.4 Per Cent

Time Seconds	Stator Current Per Cent		Input Per Cent		Tachometer Reading	Speed—Per Cent
	Amps.	0.10 = 10 Per Cent	Kw.	0.10 = 10 Per Cent		0.10 = 10 Per Cent
0	78	0.69	76	0.061	0	0
5	80.5	0.72	81	0.065	90	0.10
10	80	0.71	87	0.070	170	0.18
15	79	0.70	90	0.072	240	0.26
20	76	0.68	92	0.074	320	0.35
25	68	0.60	90	0.072	410	0.45
30	66	0.58	90	0.072	500	0.54
35	61	0.54	80	0.064	550	0.60
40	53	0.47	64	0.051	640	0.70
45	48	0.43	60	0.048	700	0.76
50	42	0.37	54	0.043	750	0.82
55	40	0.35	44	0.035	810	0.88
60	30	0.27	38	0.030	830	0.90
65	28	0.25	30	0.024	855	0.93
70			24	0.019		
75			16	0.013		

Tachometer 2/8 = Speed 290 r.p.m.

The determination of the torque characteristics of a synchronous motor, as it comes up to speed, is usually made by what is known as a "Running Torque Test." The motor is connected to a direct-current generator, and operated as an induction motor at reduced voltage. The load on the generator is increased by steps and readings taken of input to the motor, output from the generator and the speed. From these readings the torque curve can be obtained by well known methods.

The method of testing is subject to two marked disadvantages; it is usually difficult and expensive to make the tests, and the motor must be operated with high currents in the amortisseur windings for longer periods than the winding can stand without excessive heating.

The following method of determining the torque characteristics from test obviates both of the disadvantages just mentioned, and gives results which in most cases are practically as accurate as those obtained from the running torque test.

Method of Testing

The torque of a motor expressed in synchronous kilowatts is equal to the rotor input, and is, therefore, equal to the input to the stator minus the losses in the stator. These stator losses are usually comparatively small and may be easily determined, hence the torque of the motor can be obtained from readings of stator input as accurately as necessary for practically all applications of the motors.

This makes it practicable to obtain the entire torque characteristics of a synchronous motor simply by holding the impressed voltage constant and reading stator current, stator kilowatt input, and rotor speed as the motor comes up to synchronous speed. It usually requires from 45 sec. to 2 min. for a motor without load to accelerate to full speed, and readings can be easily taken at 5-sec. intervals, hence a very satisfactory input curve can be obtained on practically any motor. If the motor is connected to a load, the time of acceleration will be increased, but since the torque curve is obtained from simultaneous values of input and speed, the pres-

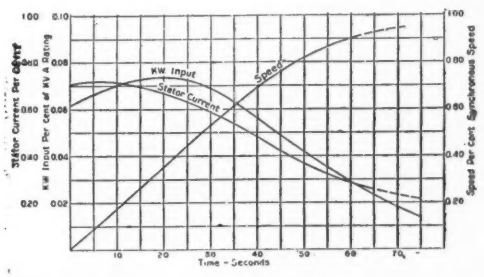


FIG. 1. STARTING TEST CURVES WITH RESPECT TO TIME FOR A 1250-KV.A., 25-CYCLE, 6400-V., 300-R.P.M. SYNCHRONOUS MOTOR AT 24.4 PER CENT VOLTAGE

ence of the load does not complicate the testing. Since it requires only a few minutes to run any one curve, it is possible to obtain data on a motor for a number of different starting conditions in a very short time. The amortisseur winding is required to carry current only for the time of a normal starting cycle, therefore there is no liability of overheating this winding.

The limitation of this method is of course the assumption that all of the rotor input is polyphase, because the force resulting from a single-phase component of input is radial and not tangential; however, with a properly designed rotor and a balanced polyphase supply, the accuracy of the test is usually sufficient for any practical purpose.

Example of Tests and Calculations

The application of this method of testing to a 1250-kv.a. synchronous motor, part of a frequency converter, will be given together with the calculations for obtaining the torque characteristic from the test data. The curves and calculations are all made on the percentage basis, which is usually most convenient for this work and gives a very good means of checking the accuracy of the tests and calculations. It should be especially

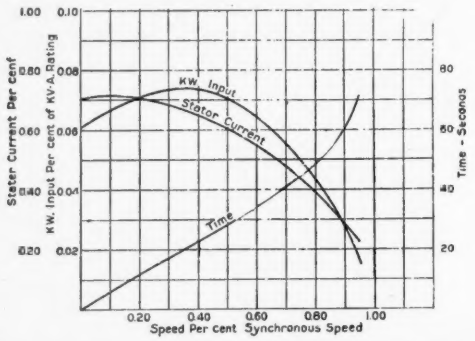


FIG. 2. STARTING TEST CURVES, WITH RESPECT TO SPEED, FOR A 1250-KV.A., 25-CYCLE, 6400-V., 300-R.P.M. SYNCHRONOUS MOTOR AT 24.4 PER CENT VOLTAGE

noted that in the calculations and curves the percentage is expressed as a decimal fraction; that is, 0.10 = 10 per cent.

The actual readings of stator current, kilowatt input to stator, and speed are given in Table I together with the per cent values. The stator current is expressed in per cent of the rated current at 1250 kv.a. 6400 v., the kilowatt input in per cent of kilovolt-ampere input rating, and the speed in per cent of synchronous speed. The per cent values are plotted in Fig. 1. Since the torque is usually desired as a function of the speed, the results are transferred to Fig. 2, which is plotted with speed as abscissas.

TABLE II. CALCULATION OF ROTOR INPUT, KV.A. INPUT AND POWER FACTOR

Speed Per Cent	Kw. Input Per Cent	Stator Current Per Cent	Stator I^2R + Short Circuit Core Loss Per Cent	Rotor Input Per Cent	Voltage Per Cent	Kv.a. Per Cent	Power-factor
0	0.061	0.70	0.008	0.053		0.171	0.36
10	0.067	0.71	0.009	0.058		0.174	0.38
20	0.071	0.71	0.009	0.062		0.174	0.41
30	0.073	0.68	0.008	0.065		0.166	0.44
40	0.074	0.65	0.007	0.067		0.159	0.46
50	0.070	0.60	0.006	0.064		0.146	0.48
60	0.064	0.55	0.005	0.059		0.134	0.48
70	0.055	0.48	0.004	0.051		0.117	0.47
80	0.044	0.39	0.003	0.041		0.095	0.46
90	0.028	0.28	0.002	0.026		0.068	0.41
95	0.016	0.22	0.001	0.015	0.244	0.004	0.30

In per cent 0.10 = 10 per cent.

Table II shows the calculation of the rotor input, which is the stator input minus the stator I^2R loss and short-circuit core loss. Since the motor is started at only 24.4 per cent of normal voltage, the stator core loss is negligible. It has been found from comparisons of running torque tests with tests made by this method that the results obtained are practically the same for motors with well designed rotors.

The values of rotor input, which also is the torque in synchronous kilowatts from Table II, are plotted in Fig. 3. The rotor I^2R loss is equal to the rotor input multiplied by the slip. The friction and windage at normal speed is from test data, and the values for the lower speeds are assumed. The total rotor loss is the sum of the I^2R loss and the friction and windage. The difference between the total input and the total loss in the rotor represents the kilowatts available for acceleration of the rotor. This acceleration kilowatt curve is also given in Fig. 3.

The time required to accelerate the rotor running without load may be calculated from the moment of inertia of the rotor and the acceleration kilowatt curve. The calculated speed-time curve is plotted in Fig. 3 and very closely checks the test curve. The method of calculation of this speed-time curve is quite interesting and is given in the appendix.

Conclusions and Notes

The method of testing outlined gives a very convenient and quite accurate means of obtaining the torque characteristics of a synchronous motor without danger of injury to the amortisseur winding.

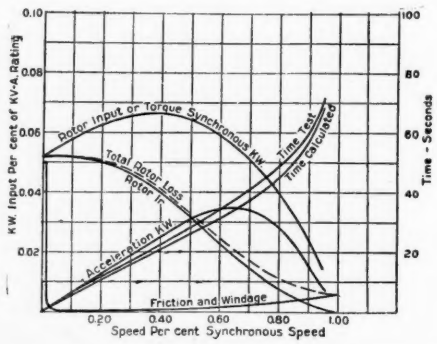


FIG. 3. CURVES FOR CALCULATION OF SPEED TIME CURVE OF A 1250-KV.A., 25-CYCLE, 6400-V., 300-R.P.M. SYNCHRONOUS MOTOR, DATA FOR 24.4 PER CENT VOLTAGE

From Fig. 3 it is possible to derive the curve of rotor loss plotted against time from which the heating of the amortisseur winding during the starting period may be estimated approximately.

TABLE III. CALCULATION OF SPEED-TIME CURVE

$E_R = \frac{0.233\ N^3WR^2}{10^9} = \frac{0.233 \times 300^3 \times 94000}{10^9} = 1980$ kw.-sec.

$WR^2 = 94000$ $\quad N = 300$

$t_s = \frac{E_R}{\text{kv-a. rating}} = \frac{1980}{1250} = 1.58$

Speed Per Cent	K	K_{t_s}	Ave'l Kw. Per Cent 0.10–10 Per Cent	Seconds for Interval	Total Seconds
0.10	0.01	0.0158	0.003	5.3	5.3
0.20	0.03	0.0475	0.009	5.3	10.6
0.30	0.05	0.079	0.016	5.0	15.6
0.40	0.07	0.111	0.022	5.0	20.6
0.50	0.09	0.142	0.028	5.1	25.7
0.60	0.11	0.173	0.033	5.2	30.9
0.70	0.13	0.205	0.035	5.9	36.8
0.80	0.15	0.236	0.032	7.4	44.2
0.90	0.17	0.268	0.022	12.2	56.4
0.95	0.0925	0.146	0.012	12.1	68.5

The speed-time curve as derived is of interest generally only to the designing engineer, but if the motor is connected to a variable load, such as a compressor, the curve of the torque required by the load may be estimated by separating the rotor loss and acceleration kilowatts from the total rotor input. The WR^2 or moment of inertia of the rotor can be obtained from the manufacturer, and from this data and the test rotor input

and the speed-time curves the acceleration kilowatts can be calculated.

APPENDIX: CALCULATION OF SPEED-TIME CURVE

THE ENERGY of rotation of a mass expressed in kilowatt-seconds is given by the equation

$$En = 0.233\ N^2\ W\ R^2 \div 10^6$$

where N = r.p.m.

$W R^2$ = moment of inertia in lb. ft.^{2}

Let t_0 = time that the stored energy of the rotor will give a kilowatt output equal to the kilovolt-ampere rating of the machine.

Not that $2\,t_0$ is the time required to stop the rotor by applying a constant torque corresponding to a kilowatt output equal to the kilovolt-ampere rating. In other words, this constant torque is

$$7040 \times \text{kv.a. rating} \div \text{r.p.m.}$$

Then t_0 = En ÷ kv.a. rating.

Since the energy of the rotating mass is proportional to the square of the speed, the energy at 10 per cent speed is 0.01 of the energy at normal speed, and the energy at 20 per cent speed is 0.04 of the energy at normal speed. Hence the change in energy from zero to 10 per cent speed is 0.01 and the change in energy from 10 to 20 per cent speed is 0.04 — 0.01, or 0.03. The change in energy expressed in per cent as a decimal for 10 per cent intervals of speed from zero to 90 per cent speed is given as K in Table III. The change from 90 to 95 per cent speed is derived similarly, and is also given in this table.

The actual change in energy in kilowatt-seconds during any interval is K En.

The average acceleration kilowatts in per cent may be read from the curve in Fig. 3 and the actual acceleration kilowatts is equal to acc'l. Kw. per cent (acceleration kilowatts in per cent) times the kilovolt-ampere rating.

Then the time t for accelerating during any interval is equal to the accelerating energy in kilowatt-seconds divided by the average kilowatts during that interval.

$$\text{Then } t = \frac{\text{K En}}{\text{Acc'l. kw. per cent} \times \text{kv.a. rating}}$$

$$\text{But } \frac{\text{K En}}{\text{kv.a. rating}} = \text{K } t_0$$

$$\text{Hence } t = \frac{\text{K } t_0}{\text{Acc'l. kw. per cent}}$$

As illustrated in Table III, the time for acceleration for each of the various intervals may be calculated, and a summation of these values gives the speed-time curve. The interval in speed must be small enough so that the average kilowatts over the time interval is approximately equal to the kilowatts for the average speed. The intervals chosen in Table III give very satisfactory results. A comparison of the test and calculated curves in Fig. 3 shows that the calculated curve is very close to the test curve in both shape and actual values.—General Electric Review.

Pacific Gas & Electric Co. Substation and Transmission Line

FEATURES REGARDING THE DESIGN AND CONSTRUCTION OF 220,000-V. SUBSTATION AND TRANSMISSION LINE. BY CHARLES W. GEIGER

FROM THE hydroelectric power developments on the Pit River, described in the Jan. 15 number, there is being constructed at the present time, a double circuit transmission line for 220,000 v., and the first substation which is to be the terminal of the projected 220,000-v. lines carrying energy to the San Francisco district.

The substation, known as the Vaca Substation, is being built on a 90-acre tract fronting the state highway between Vacaville and Sacramento, 4½ mi. northeast of Vacaville. It will serve two purposes: first, to transform the Pit River power from 220,000 v. to 110,000 v., so that it may be distributed to the cities and regions bordering San Francisco bay; and second, to regulate the voltage of the power received and thereby secure the most economical transmission and the best service.

The main substation building, shown in Fig. 1, designed in an adaptation of the Spanish renaissance, consists of a main front portion 42 ft. 8 in. by 128 ft. in plan, with a rear wing 38 ft. 2 in. by 91 ft. The front of the building will house two 20,000-kv.a., 11,000-v., three-phase, 60-cycle, 600-r.p.m., horizontal revolving field synchronous condensers with direct connected exciters. This main condenser room extends 38 ft. 3 in. from the floor level to the bottom of the roof trusses.

The 11,000-v. bus structures and switching devices are housed on the first floor of the rear wing, while the second floor will include the point of control for all equipment and will contain, in addition to the switchboard, a store room, telephone booth and lavatory.

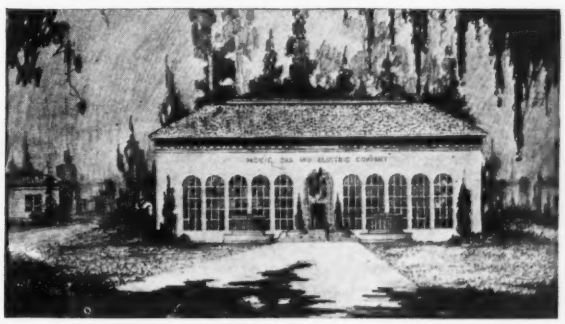


FIG. 1. ARCHITECT'S DRAWING OF VACA SUBSTATION

The building is a steel and reinforced concrete structure with Spanish tile roofing, and an outside finish of light buff plaster. The predominating exterior feature on the front of the building consists of a semicircular niche with an ornamental cast cement emblem overhead and framed with an ornamental lattice border. Circular cement steps will form the approach to the enclosure from which the public will be able to obtain a good view of the interior of the station. An artistic pond with fountain will be located immediately in front of the building, giving a pleasing appearance to

the substation setting. It will be the largest and most important substation on the Pacific Gas & Electric system.

All the switches will be mounted on fireproof steel construction. The main transformers, high tension oil switches, high tension air switches and high tension busses will be installed outdoors. This equipment comprises: Seven 16,667-kv.a. single-phase, oil insulated, water cooled, auto transformers, 220,000-v. high tension to 100,000-v. low tension, with tertiary winding for 11,000 v. for synchronous condensers and with tap for operating at 160,000 v. One of these transformers is to be held as a spare. There will be a seven-section 110,000-v. double bus structure, with disconnecting switches, seven 110,000-v. oil switches and three 220,000-v. oil switches.

Heavy equipment will be hauled over dirt roads from Hartley, about 3 mi. from the substation site, thus keeping off the highway.

A model camp for 100 men engaged in constructing the station has been built. This camp is of a semi-permanent nature made up of frame buildings of sur-

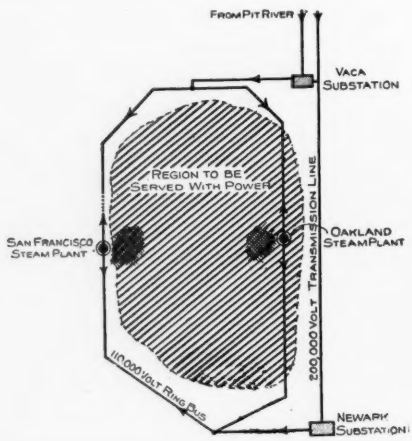


FIG. 2. RING BUS ENCLOSING SAN FRANCISCO BAY DISTRICT, FED AT TWO POINTS WITH PIT RIVER POWER

faced lumber and painted, with the view of leaving it available for enlarging the substation in another 5 yr.

There will be eight cottages for accommodating the operators, a large garage and a separate building housing the pumping plant for cooling water and domestic use. The project will cost about $1,250,000.

THE 220,000-V. TRANSMISSION LINE

THE TRANSMISSION line connections will include two lines of two circuits, each 201.5 mi. long, from the Pit No. 1 power house and made up of 27.7 mi. of 518,000-circular mil steel core aluminum cable and 173.8 mi. of 500,000-circular mil copper cable. There will also be an incoming and outgoing circuit connecting to the 110,000-v. Drum-Cordelia line of 3/0 copper cable, and two circuits to the Clairmont substation, Oakland, made of 250,000-circular mil copper.

The reason for using the 518,000-circular mil steel core aluminum cable on the 27.7 section was to withstand the weight of snow, the aluminum not being sufficiently strong, so 37 aluminum wires were used with 19 steel wires, the aluminum providing the necessary conductivity and the steel wires the strength. The cable for this distance is concentric strand, while the 173.8 mi. of copper consists of 49 wires with rope strand.

The steel that enters into the construction of the transmission line towers is manufactured according to the following minimum specifications: yield point 45,000 lb. per sq. in., ultimate strength 60,000 lb. per sq. in. and 22 per cent elongation. This product is a carbon steel from open hearth furnaces. The possibility of producing a carbon steel with these unusual specifications on the Pacific Coast had been questioned, and to refute this a test was arranged and conducted at the plant under the direction of C. T. Wiskocil, Associate Professor of Civil Engineering, in charge of the Materials Testing Laboratory of the University of California.

Samples of steel angles were selected at random from a stock of more than 1000 T. of tower steel of various thickness, and tested on a 200,000-lb. Reihle universal testing machine. The average of the tests showed that the steel had an elastic limit of 46,800 lb. per sq. in., by the drop of the beam, a breaking strength of 68,400 lb. per sq. in. and an elongation of 25.2 per cent.

Steel of this quality has been furnished for the past 2 yr. in transmission towers and records of 250 consecutive tests made upon this material indicate that this high average has been uniformly maintained.

The transmission line parallels the railroad tracks for a distance of about 100 mi., being, however, about 5 to 7 mi. away from the railroad. The steel for the transmission lines is stored at points 15 to 20 mi. apart, from which points the steel is distributed by a fleet of motor trucks operated by the construction department of the Pacific Gas & Electric Co. In many places it is necessary to construct roads, while in other places the trucks run through rice fields and stubble fields. Advantage must be taken of the dry season in hauling the construction material. Work can be carried out on the transmission line in the valley the year around except during the heavy rainy season. In some of the mountain sections the snow is sometimes 15 to 20 ft. deep, and here, of course, advantage must be taken of the favorable weather for construction work.

The members of the construction gangs live mostly in tents which are made especially for this work. Each sleeping tent is 16 by 18 ft. and accommodates five men. A special tent for the kitchen and dining room is provided for each separate construction gang. These tents usually seat from 60 to 70 men at one time. The kitchen is provided with screens on two ends and on the side to keep out mosquitoes. In the mountain sections, however, more substantial camps are provided.

The concrete for the tower foundations is mixed by a mixer operated by gasoline engine. In the mountain section, it is difficult to obtain aggregate; but in the valleys, it is usually easy to find gravel from the streams which the transmission line crosses. In some sections of the mountains it is necessary to install portable rock crushers.

A motor truck equipped with a demountable tank of 1050 gal. capacity is used for the purpose of hauling water used in mixing concrete and for domestic use. This truck is 4½ T. and is operated day and night.

The transmission towers in the valley are 97 ft. high, weigh 8000 lb. and are spaced 800 ft. apart. The valley towers carry the transmission wires so that they are spaced vertically 15 ft. and horizontally 24 ft., and the snow towers (used in the mountain sections where there is heavy snow fall), carry three transmission wires spaced 19 ft. horizontally. The lines are transposed at intervals of 6 mi. by means of transposition towers, consisting of two standard towers 97 ft. high, connected with two bridges 29 ft. long and two arms on each tower. In the valley, anchor towers of 12,000 lb. each the transverse pull of 8800 lb. being to take care of any load due to wind on the wires and the tower itself, together with an allowance for a slight angle in the line.

Another test represented a case in which all six wires were broken on one side of the tower, at once, leaving a load of 10,200 lb. applied at the end of each arm. The vertical load, as in test No. 1, represented the weight of the wire, and the transverse pull of 7900 lb. is the wind load. This is the largest known test applied to a tower of this kind, giving a total breast pull of 61,200

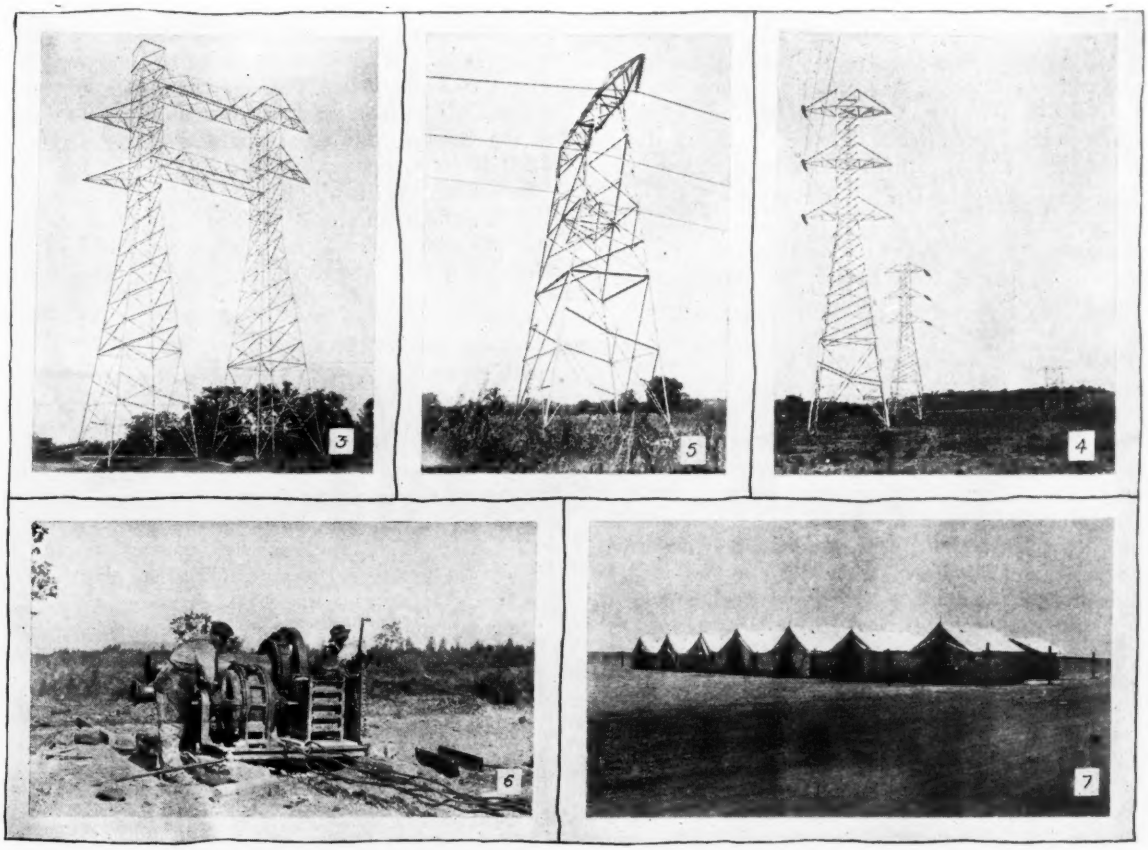


FIG. 3. TRANSPOSITION TOWERS, PLACED AT 6-MI. INTERVALS. FIG. 4. VALLEY TOWERS. FIG. 5. SNOW TOWERS. FIG. 6. ELECTRIC HOIST USED IN CONSTRUCTION OF 220,000-V. LINE. FIG. 7. GENERAL VIEW OF CONSTRUCTION CAMP

are placed at all angle points and at other points where special anchors may be necessary.

Testing the Towers

As evidence of the unusual merit of the steel used in the towers for the line, the towers were constructed with from 25 to 35 per cent less steel than was thought necessary otherwise. Exhaustive tests were made to prove that the steel was strong enough to carry the required load.

The tests were carried out at the plant of the Pacific Coast Steel Company in San Francisco. One of the tests represented a condition in which three wires were broken on one side of the tower, causing a pull of 10,200 lb. on the end of each of the three arms. The vertical loads of 1400 lb. each represented the weight of the wires, lb., a total vertical load of 8400 lb. and a transverse pull of 7900 lb., or a total load of 77,500 lb., or 38.8 T., besides the weight of the tower.

Proposed Community Center at Pit River No. 1 Development

In connection with the foregoing account of what is being done in the construction of the transmission line and substation, a word or two regarding the accommodations which are to be provided for the employes at the Pit River No. 1 plant may be of interest. These employes, it must be remembered, are more or less isolated from cities or towns and one of the important features in a hydroelectric development of this kind, is the proper housing and the provision for recreational opportunities for the employes and their families.

The Pit River No. 1 plant is the largest in course of construction and when completed will require between 14 and 18 men to operate it, a proportion of whom will be men with families, so the community can easily consist of from 30 to 40 people. The location of this plant makes it a beautiful spot to be isolated in, but one in which it is necessary to anticipate the needs of those who are to dwell there, so that, whatever the time of the year, their welfare is assured.

The power house itself is at the foot of a mountain on a slightly sloping stretch. Back from the river about 1000 ft. this slightly sloping stretch continues both ways from the power house north and south and is quite heavily wooded with pines and oaks. It is on this slope by the river that the Pacific Gas & Electric Co. is preparing to establish a community center for the accommodation not only of residents, but also of other members of the Pacific Gas & Electric Co., whose duties from time to time may call for a sojourn at Pit No. 1.

This community center consists of one large club house in which it is proposed to take care of all single men, guests and work crews; six cottages for the men with families, four of these having four rooms and two having five rooms, a large garage and a warehouse in which will be located the postoffice.

Their location has been studied in reference to the power house so that they will be convenient in distance and yet far enough removed to form a unit in themselves. The warehouse and garage have been placed at the intersection of the road which passes through the plant to Fall Rivers Mills, and the railroad, which is a point midway between the community center and the power house itself. This being the center of all incoming and outgoing vehicles, mail and supplies, will be found convenient to both the community center and the power house requirements.

The club house will be the central building of this community and also the center of all social activity of four power plants within a few miles radius, consisting of Hat Creek Nos. 1 and 2, and Pit River Nos. 1 and 2. In plan the buildings consist of a central portion and two wings. In the center portion are located the living room, billiard room and dining room, with the accompanying kitchen, cold storage and store room equipment. The east wing contains the bed rooms for the operators and two large guest chambers. The west wing is the portion to be occupied by working crews who may come in from time to time, having a large living room, individual bed rooms and porch.

Social activities will adapt themselves readily to the layout of the living, dining and billiard rooms, because, in addition to performing their individual functions, these three rooms can be combined into one large floor area forming a most ideal nucleus for the community center. This feature of the club house, it is felt, will prove a vital factor in solving the problem of what to do with the leisure hours, preventing them from becoming irksome in the semi-isolation of these plants, and should contribute largely to the development of a wholesome and friendly spirit.

Considerable study has been given the cottages to provide ample room and equipment for the families that will be required to live in this region, and they have been designed in the same style as the club house, using the native rock for foundations and combinations of rustic exterior coverings, so that each cottage will possess an individuality of its own. The living rooms of these cottages will be finished similarly to the living room of the club house, and each will contain an open fireplace.

The appointments of both the club house and the cottages, such as kitchen sink, bath room fixtures and laundry, will be similar to those in modern city cottages. The water, fire protection, sewer and lighting systems, when complete, will lack nothing in the way of modern and necessary conveniences to make living on the part of these people as delightful and safe as possible. The club house equipment will include a complete cold storage plant. In addition to the refrigeration needed at the club house, ice will be manufactured to supply the needs of the families of the community center and, also, the families residing at the other power plants on the Pit River system.

Recreation has likewise been given thought, and provision is made in an area of ground in front of the club house for such games as all concerned would be likely to indulge in, the present suggested games being tennis, croquet, horseshoe and bowling.

Income Tax Facts

IN making out his income tax return for 1921, the taxpayer will find that the exemptions provided by the revenue act of 1921 are $1000 for single persons (the term including widows, widowers, divorcees, and persons separated from husband and wife by mutual agreement), $2500 for married persons whose net income was $5000 or less, and $2000 for married persons whose net income was $5000 or more.

The exemptions for dependents—a person who receives his chief support from the taxpayer and who is under 18 yr. of age or incapable of self-support because mentally or physically defective—is increased from $200 to $400.

The act requires that a return be filed by every single person whose net income for 1921 was $1000 or more, every married person whose net income was $2000 or more, and by every person—single or married—whose gross income was $5000 or more.

The requirement to file a return of gross income of $5000 or more regardless of net income is a new provision. Net income is gross income less certain specified deductions for business expenses, losses, bad debts, etc., which are fully explained on the forms.

Returns must be filed by married couples whose combined net income for 1921, including that of dependent minor children, equaled or exceeded $2000, or if the combined gross income equaled or exceeded $5000.

The period for filing returns expires March 15, 1922. Heavy penalties are provided for failure or "willful refusal" to file a return on time.

Forms 1040A for incomes of $5000 and less and 1040 for incomes in excess of $5000 may be obtained from the offices of collectors of internal revenue and branch offices. The tax may be paid in full at the time of filing the return, or in four equal installments, due on or before March 15, June 15, Sept. 15 and Dec. 15.

Passenger Elevator Protection

ARRANGEMENT AND SAFEGUARDING TO PREVENT ACCIDENTS AND REDUCE FIRE HAZARD TO A MINIMUM. BY J. J. LAMB*

IN a large city with high office, store, and factory buildings, the number of passengers carried by elevators—counting each trip separately, is greater than that carried on street cars. Most office workers, a large percentage of factory and retail store workers, and practically all customers in any of these establishments use the elevators. While elevator accidents are few, in proportion to the number of passengers, still the great number of passengers carried, and the fact that a large percentage of elevator accidents result in death or permanent injury make it desirable to adopt all practicable safeguards.

HOISTWAYS

EXPERIENCE has demonstrated the value of the elevator as a life-saving device in case of fire, and a simple form of fire-resisting construction will usually keep the fire from the hoistway for a greater length of time than the elevator need be used as an exit from a burning building. Such enclosures also prevent the rapid spread of fire from floor to floor. Fire-resisting hoistway enclosures are therefore recommended for all elevators.

Where two or more elevators are in adjacent hoistways, the clearance between adjacent cars should be not less than 2 in. Outside windows, below the seventh floor, on elevator hoistways should be barried or grated on the outside to prevent firemen from breaking through, with the possibility of falling down the shaftway or at least of increasing the draft for the fire. By having hoistway windows barred, time is saved the firemen in setting and climbing ladders only to find that there is an elevator hoistway, and in some cities grating on the outside of such windows is required as a notice to the firemen. It is also customary in some cities to put signs outside these windows to indicate that an elevator shaft is inside.

Overhead beams in the hoistway should be placed high enough so that the car can travel at least 2½ to 7 ft., according to the specified speed of the elevator, above the highest landing. Above the beams there should be sufficient head room for the safety and convenience of men inspecting or repairing the machinery or sheaves.

All electrical conductors installed in elevator or counterweight hoistways should be in metal conduits or of armored cable with the exception of flexible cables connecting the car with the fixed wiring. All the metal-inclosing covering of the electrical apparatus should be thoroughly grounded, preferably to water pipes—never to gas pipes. No pipes except those used to furnish or control power for the elevator or hoistway should be installed in the hoistway. Care should be taken to see that there are no connections, openings, tunnels, or outlets within the hoistway except those having to do with the operation of the elevator.

No part of any electric circuit whose voltage rating exceeds 750 should be permitted in any elevator hoistway, or to be connected to any control switch or signal system.

Where a fireproof enclosure is not provided, the hoistways should be enclosed to a height of not less than 7 ft. from each floor on all but landing sides. Where an elevator is located adjacent to a stairway, that portion of the hoistway adjoining the stairway should be enclosed to a height of not less than 7 ft. above each stair tread. The hoistways of passenger elevators should be enclosed from the floor to the ceiling on the landing sides.

LANDINGS

STATE and city requirements vary as to the type of doors to be used at elevator landings. In general, horizontal sliding doors, with interlocking devices, are the rule. The use of swinging doors is not advisable. Landing doors should be equipped with a self-action lock which requires a key or special mechanism to open it from the landing side, the key being kept by a responsible person.

No automatic fire door, the functioning of which is dependent upon the action of heat, should be used to close any landing opening in the hoistway of any passenger elevator nor any exit leading from any hoistway landing to the outside of the building.

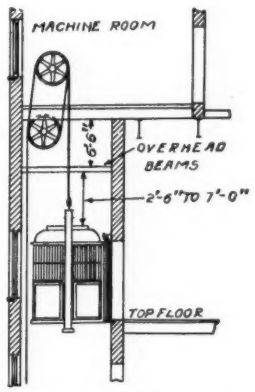


FIG. 1. PROPER ARRANGEMENT OF OVERHEAD BEAMS IN HOISTWAY

For a distance of at least 2 ft. back from in front of the door, the landing platform should have no exposed metal or slippery material upon which one is liable to stand. It is much better to use rubber mats, firmly secured, or some anti-slip material, directly in front of all landing doors of the hoistway.

To insure the positive closing of the landing hoistway doors for passenger elevators there are a number of devices on the market which prevent the elevator from moving up or down until the landing door is closed. The two types are (a) purely mechanical, (b) electrical-mechanical. Some states require the use of an interlock, a device which, in addition to preventing movement of the car when the landing door is unlocked, also prevents the opening of the landing door from the landing side unless the car is at the landing. Some types require only that the landing door opposite which the

* Formerly Safety Engineer, National Safety Council.

car is standing, be closed and locked; others require that all landing doors be closed and locked before the car can be moved.

Electric contact devices perform only one of the two functions of the interlock; that is, they prevent the movement of the car unless the landing door is closed. In the case of electric contacts the landing door is considered as being closed when it is within 2 in. of the fully-closed position. In the case of interlocks the landing door is considered as being locked if it cannot be opened from the landing side more than 4 in.

Every interlock or electric contact should be provided with an emergency release device which will permit the operation of the car regardless of the position of the doors, in case of fire or other emergencies. This release should be placed in a box with a glass front which can be easily broken when necessary, should be plainly visible to the occupants of the car, and accessible, but not easily so, to the operator. It should never be

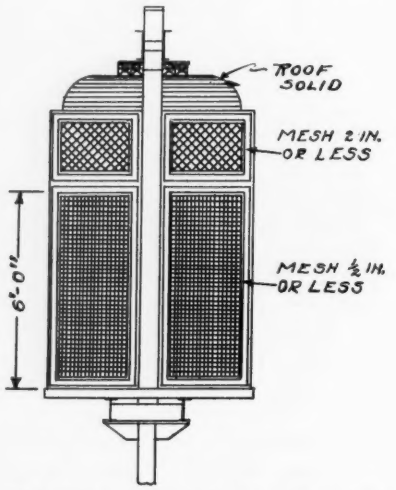


FIG. 2. SAFE METHOD OF ENCLOSING PASSENGER ELEVATOR CAR WITH OPEN WORK SIDES

used except under extraordinary conditions. If used, an explanation should be forthcoming, and a new piece of glass should be immediately placed on the front. The interlock or electric contacts should not prevent the movement of the car when the emergency release is in temporary use or when the car is being moved by a car-leveling device.

Landing doors closed by hand should be arranged so that it is not necessary to reach back of any panel, jamb, or sash to operate them.

It is important to provide sufficient light at the floor level of each landing. The American Society of Mechanical Engineers standard is three-fourths that given by a standard candle 1 ft. distant.

Car Construction and Safeties

No material not a permanent part of the elevator equipment should be permitted on the top or cover of the elevator car. All passenger elevator cars should be enclosed on all sides not used for entrances and on the top.

Enclosures may be made of metal or wood, solid or openwork. The car sides, to a height of 6 ft. from the car floor, should contain no openings larger than ½ in.; above that openwork design may be used, the opening of which will not pass a ball 2 in. in diameter. The car enclosure should be firmly secured to the car floor in such a manner that it cannot work loose or become displaced in ordinary service.

Mirrors in elevators are dangerous as they are likely to confuse the passengers and are also a source of danger through breakage in case of the dropping of the elevator car, the sudden application of safeties, or the car striking bumpers.

Ample light should be provided in the car at all times.

In some plants elevators are used for combination freight and passenger service, such as passenger service during the change of shifts and freight service during the rest of the day. In such cases, if a gate on the car is not practicable, it is suggested that a row of large headed nails be driven across the elevator floor about 2 ft. back from the landing edge, and that the operators of the elevators be given positive instructions not to move the cars should any one be forward of the line.

State and city laws provide that all elevators except the direct plunger type shall have speed governors. Such a speed governor operates the device clamping the car to the guides when the car attains excessive speed in its descent caused by the breaking of the cables or other derangement of elevator equipment. The minimum diameter of the governor cable should be not less than ⅜-in. All governors to operate car safety devices should be set to trip at not more than 40 per cent above normal car speed, except that when normal speed exceeds 550 ft. per min. the trip should operate at 30 per cent overspeed. No gripping portions of any safety device should be used to guide the car. The type of safety device should be such that when applied any further motion in the same direction will not release the gripping devices in the event of the adjustment being faulty; and in the event of tension on the governor being released, the gripping devices should remain engaged. The speed governor should be plainly marked with the rate of speed at which it is set to trip.

Before placing a new or repaired passenger elevator in service, tests should be made to determine whether the car attains the rated capacity, and at the same time the "safety" and speed governor should be tested. In addition there should be periodic tests of all passenger elevators.

Counterweights

Counterweights should necessarily run in grooves. If two counterweights run in the same guides, the car counterweight should be located above the machine counterweights with a minimum distance of 8 in. between them, so that in case of failure of the machine counterweight cables the entire load of both counterweights will not pull on the car counterweight cables, as this would result in pulling the car, if nearly empty, into the overhead works. It is better to run the two counterweights in separate guides.

In case independent car counterweights are used, they should be of such weight as not to cause slack in any cables when an unloaded car is accelerating or decelerating.

All counterweights should be held together by tie rods having lock nuts and cotter pins, these rods passing directly through all the weight sections. It is further advisable to hold the counterweights in a frame.

Bumpers and Guides

Spring type bumpers or their equivalent are necessary on all passenger elevators, and should be able to stop the car at a rate of not more than 64.4 ft. per sec. At this rate, the pressure on a person's ankles is three times the normal pressure of the person's weight. Bumpers of spring type or equivalents should be put under all counterweights. Spring bumpers should be supplied up to the speed limit of 250 ft. per min. For greater speed, oil bumpers or their equivalent should be used. In designing plunger elevators, provision should be made to stop the plungers as well as the car. On other types of elevators care should be taken to locate the bumpers or buffers symmetrically with reference to the center of the car sling.

All power passenger elevators should have steel guide rails for both the car and the counterweight. These guide rails must be firmly fastened to the hoistway with iron or steel brackets designed to stand any stress or strain which may occur in the operation of the elevator either under normal conditions or when the safety stop may have to come into operation. Neither guide rails nor brackets, under normal operation, should deflect more than ¼ in. The guide rail surface of the car and counterweight must be smooth, and be kept well lubricated, with the joints an accurate fit.

Operating Machinery

All hoisting drums and sheaves should be of cast iron or steel, designed with factor of safety of 10, and should have machine-cut grooves not more than 1/16 in. larger than the ropes or cables. The factor of safety is based on the minimum carrying capacity of 75 lb. per sq. ft. plus the weight of the car, cable and counterweight.

All machines should have brakes, applied automatically by gravity or springs when the control is at the "stop" position, and released electrically, in the case of electrical machines, by throwing the control mechanism into starting position. The brake shoes should be independent in action, either shoe being capable of stopping the car.

Needless to say, proper safety guards should be provided on all elevator machines in accordance with the safety regulations governing machinery in general.

Hoisting Cables

Car and counterweight cables should be of steel or iron (no chains should be used for hoisting), long enough so that not less than one turn of cable remains on any winding drum when the car or counterweight has reached the extreme limit of its travel. No car or counterweight cable should run over a sheave or be wound on a drum whose diameter is less than thirty-eight times the diameter of the cable.

Equalizers

Equalizers should be provided at car and counterweight ends of hoisting cables for traction elevators having only two cables. Equalizers should be provided for elevators having winding drums, if the cables wind in grooves on drums scored right and left hand. The National Safety Council recommends that where practical equalizers should be used if several hoisting cables are attached to a car or a counterweight. It is also recommended that for traction elevators the equalizers consist of compression springs located between the crosshead and the cable anchorage.

Control

No passenger elevator, having a speed greater than 100 ft. per min., should be controlled by a hand operated rope or cable. No elevator whose maximum speed exceeds 150 ft. per min., except a hydraulic elevator, should be controlled by a rope or cable operated by wheel or lever mechanism. All overhead tension weights for hand ropes should be secured by chains attached to the weights and to a suitable anchorage. Groove guards should be provided on all operating

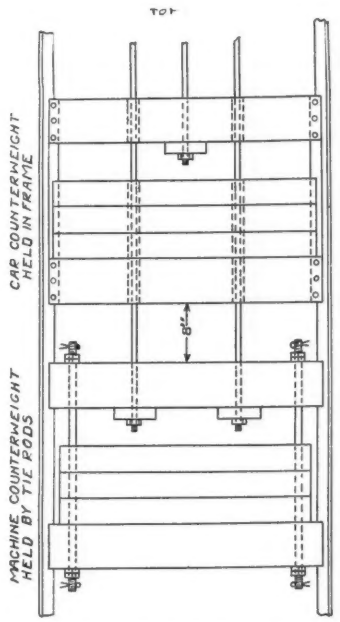


FIG. 3. ARRANGEMENT OF CAR AND MACHINE COUNTERWEIGHTS

sheaves to keep the cable on the sheaves at all times. On mechanically controlled elevators the operation of direction switches or operating valves should not depend solely upon belts, cast or malleable chains.

Controller or operating switch of every electrically controlled elevator should be self-centering and self-locking; that is, it should return to neutral when the hand of the operator is removed.

Every electrically controlled elevator should have an emergency switch near the control apparatus so that the operator can cut off the power, if necessary, but no circuit breaker, operated automatically by any fire alarm system, should be so connected as to cut off the power or control from any passenger elevator.

In all types of elevators having hand lever control the levers should be so arranged that the movement of the lever toward the door which the operator usually faces will cause the car to descend and the movement

of the lever away from the door will cause the car to ascend.

Rules for Elevator Operators

You cannot run an elevator properly and safely and carry on a conversation or do something else at the same time.

Be sure that gates or doors are closed and latched and that everybody and everything is in a safe position before you start the elevator.

Always remember the safety capacity of your elevator and never allow it to be overloaded.

Bring the elevator to a full stop before you attempt to reverse its direction. Start the car slowly.

Be sure to center (place in neutral position) your hand rope, lever, wheel, or switch controller; and wait until the car has come to a full stop before you open the doors or gates.

Do not try to show off by speeding your elevator. Watch the speed carefully when going down as a heavy load may increase the speed.

Learn the emergency call (which is one long and three short rings), and get to the floor from which the call came as quickly as possible.

If the elevator does not operate properly for any reason, do not attempt to run it. Notify your superior at once.

If the safety device should operate and stop the elevator, do not attempt to start the car. If the elevator should stop between floors, keep cool and do not allow anyone to leave the car.

Do not permit unauthorized persons to operate the elevator.

Never leave the elevator unattended unless the car is empty and the doors or gates are closed and latched.

Be careful to stop the elevator with the car floor level with the landing floor. If you have failed to do so give warning by saying, "step up, please," or "step down, please,"—as the case may be. Never attempt to correct a bad stop by moving the car after the doors or gates are opened.

Fooling, scuffling or horseplay are prohibited in elevators. Require passengers to face the doors or gates, and do not allow them to enter the car until any who desire to leave have gotten off.

Remember that your life and the lives of others are dependent upon your alertness, caution, and good judgment.

Air Pressure Drop Due to Small Pipe

By W. A. Shmidheiser

A SHORT TIME ago, a complaint regarding low air pressure arose and upon inspection, the following conditions were observed: Tank work, involving the use of a number of riveting hammers and an air hoist was proceeding at a distance of approximately 3500 ft. from the power house where the compressors are located. Pressure at the power house is maintained between 100 lb. and 110 lb., averaging about 103 lb. gage. Of the 3500 ft. of piping, approximately 1300 ft. is 3 in. in diameter while the other 2200 ft. is 1½ in. in diameter. This excessive length of 1½-in. pipe of course answered the question of the low pressure at the tools when the tools were working; but in order to determine just what the effect of the 1½-in. pipe was, the following experiment was made.

There was one straight run of 1½-in. pipe 1541 ft. long without elbows or tees which furnished an excellent place for the test. Carefully calibrated gages were connected at each end and at a point approximately 1000 ft. from one end. An air meter was connected to the free end of the length and the amount of air flowing was controlled by a valve at the meter. Simultaneous readings of the gages and air meter were taken and the drop of pressure due to various flows obtained.

As the intermediate gage showed the drop in pressure to be proportional to the length of pipe, the drops

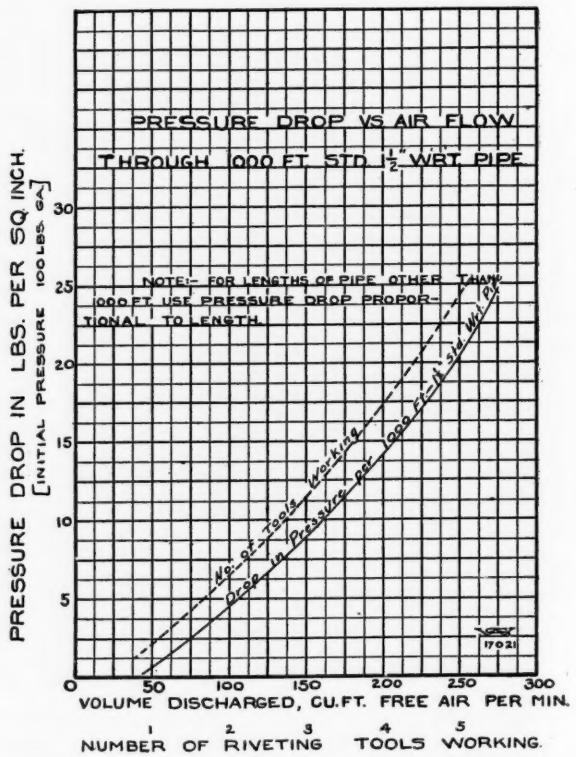


CHART FOR DETERMINATION OF AIR PRESSURE DROP THROUGH 1½-IN. PIPE

for a length of 1000 ft. of pipe were computed and have been plotted as shown by the solid line in the accompanying figure.

As a check upon this, different numbers of tools were operated at the same time and readings of the drop in pressure at the tools made. These results were also plotted and are indicated by the dotted line. The results check quite well with a number of tests made of the tools used which showed an average consumption of 59 cu. ft. free air per minute.

As an example of the use of the curve, we may assume that we will use certain tools which will have a consumption of 225 cu. ft. per minute and that the length of 1½-in. pipe is 325 ft. To determine the drop in pressure, the line representing 225 cu. ft. is followed to the solid curve, which, when followed horizontally to

the drop, indicates that drop in pressure of 17 lb. may be expected for each 1000 ft. length. For a length of 325 feet., the drop would be $\frac{325}{1000} \times 17 = 5\frac{1}{2}$ lb. approximately.

On the other hand, to determine the drop due to three tools, the line representing this number is followed to the dotted curve. Moving horizontally to the left gives a drop of pressure per 1000 ft. of approximately 11½ lb. To determine the probable air consumption, move to the right until the solid curve is encountered and then vertically downward to the volume, which in this case, for three tools, would be 175 cu. ft. of free air per minute. It is realized that the curve of air consumption and pressure drop for the tools applies only to those cases where the air consumption of the tools varies between 55 and 60 cu. ft. of free air per minute, but the curve plotted between air flow and drop will hold for 1½-in. standard pipe in all cases.

Trouble Hunting---XII

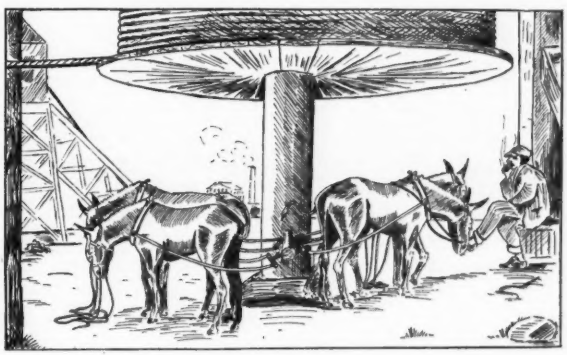
IN WHICH WE START WORK ON THE UPPER "DIGGINGS." BY JOHN PIERCE

IN GETTING ready to start operations at the No. 1 upper "diggings," I had to overhaul the hoist which was the first of that particular type I had ever seen. Most hoists are rated according to a certain horsepower, but this one was somewhat different—it was rated by mule power, and was operated by eight mules. There was a large spool built on the end of a spindle which rested on a plate on the ground. Under the spool there was plenty of room for the mules to walk around in a circle, and they, being hitched to long radial arms extending out of the bottom of the spindle to a point directly under the edge of the spool, wound up the cable as they walked around. The spool was 30 ft. in diameter. The upper part of it was supported by a frame which extended out beyond the spool and the legs which did not interfere with the mules as they walked inside of them. One team walked forward to do the pulling, and the next backward to stop the hoist in case the "go ahead" would not answer signals. The third team was cut in on the "go ahead" the same as the first, while the fourth walked backward as did the second.

The "shaft" of the mines are all two, or more, compartment shafts, and as one bucket, tub, or cage came up, the other went down. The level of this mine that was to be worked was at 400 ft. As the level of the mouth of the shaft was only 255 ft. above the shaft level at the main plant, if the mules let you go 5 ft. too far you went into the water, and, believe me boy, when you are down 400 ft. into a little dark hole, knowing there is 1850 ft. more hole under you, and that full of water, and nothing but a mule on the other end of the line, you sure do have a funny feeling chasing up and down your spine. All the light you have is a little carbide lamp, which always goes out when it shouldn't, and then one can feel the darkness closing in on him.

After rigging up my hoist, and the engineers all being at their post, a large lamp was put in a bucket and sent down. This not going out, the miners were not afraid of gas, so they went down; soon to return, saying that while the air was not killing on short time periods, it would not do to work in. The next problem, then, was to get the air to moving, and I hunted around and found a 15-hp. portable boiler that was in very good shape and a 7-hp. steam engine that I over hauled and put in good condition. I had these taken up the mountain to the shaft in question and set up the boiler. I had noticed a small 5-hp. Connersville blower among the pile of junked materials and was intending to set it up and blow air down the shaft and back into the workings. On looking it over, I found it intact except the impellers. They were gone, and could not be found. I put my head carpenter to work making a set out of wood, after getting the dimensions, and making a drawing to scale, and after they were made and worked down to a fine point, I dipped them in boiling oil and refitted them. Then I reinforced them with countersunk bolts, and took her up the hill.

By this time I found that in order to get into the station below with my 8-in. air line, I'd have to cut the lengths not over 9 ft. long or they would not pass the timbers at the mouth of the station. In addition to



OUR 8-MULE POWER HOIST

this, I found the shaft so small that putting an 8-in. pipe in the corner of the shaft would greatly interfere with the tubs. Also, the timbers and rests were all very old, and I seriously doubted if they would not give way when I had hung 400 ft. of 8-in. line on them.

Finally I dismantled the engine and the blower, taking them down the shaft in pieces, and set them up on the opposite side of the shaft in an unused station on that side. I strengthened the timbers on the middle part of the shaft and, removing one set, crossed the shaft between the two compartments with my 8-in. pipe. On this side of the shaft there was the same difficulty about admitting pipe over 9 ft. long; but we had to do it, so we began cutting and threading pipe. In the meantime I ran a 2-in. line down the shaft for steam; the engine only called for a 1-in. line, but I was allowing for distance and condensation. The exhaust I simply ran about 30 ft. down in the water; this fixed that part of it, and the men were ready to start work in No. 1.

At No. 2 we found the same conditions. After fixing up the mule power hoist we found the center

wall of the two compartments so bad I had to put my carpenters to making sets, and the timber men to taking out the old ones and putting in the new. The bad air and gas was inclined to accumulate and bother them, so I decided to run a line down this shaft and blow air down it at night and let the men work in the daytime. I found another small engine but could find no small boiler, so in casting about for some way to run the fan, for I'd found a big old fan (goodness knows what it had ever been used for), I discovered a two-hp. gasoline engine. After going over it thoroughly, babbiting all the bearings, turning out new rings for the piston, and rebuilding the magneto, I got her so she'd turn over right merrily. We took her over to No. 2 and bolted her down and belted her to the fan. I then took white muslin and made me a long muslin tube held open with wire rings and painted her with "chapopote." Had I not used the chapopote, rings would not have been necessary; but in order to prevent it rotting I gave her the oil. I let this down the shaft and started the fan. In two days the miners could proceed with the work, so we felt that we had done very well again. Mind, all this machinery was costing the company nothing, as I was getting it from the junk heap where it had been thrown as worthless.

At No. 3 we had no bad air, but as this shaft had considerable water in it and no hoist of any description we had to unwater it. This was not connected with the other workings and was not opened up at all, being just a new shaft that had been put down to 400 ft. and abandoned when the revolution started. I did not know what to do, and fell to thinking of various schemes. I tried several but none of them worked very well.

At last I built two uprights, one on either side of the shaft, and extending over both compartments. On these I mounted an axle which had a large diameter inside the uprights, on the outer end I made a flanged pulley. Over the barrel-like center I strung two cables, one running one way, one the other. As one went down, the other came up. I took two shaft bailing tubs, or buckets, which had valves in the bottom and fastened them to the ends of the cables. Over the flanged pulley at the end I wound two more cables. One went opposite the other, so that unwinding one, the other would wind up. To the ends of each of these I fastened a "singletree" and to the singletree a mule, and for each mule was a boy. The valves in the tubs had stems sticking down so that when it was lifted up a chute, or trough, was shoved under it, and slacking off a little on the mule, the stem would strike, the water run out, and the tub would be ready to go down again. It was not hard on the mules, one would run to the end of his rope and up would come his tub. As soon as it was emptied he would be unhooked and driven back for another pull; in the meantime the other mule, going in the opposite direction, would be bringing up his end of it.

The next and last shaft which we wanted to start work on had a fine old steam hoist. Double drum, and all hooked up. There was a pair of large boilers also at this place, but they had had no roof over them, had lain idle for 9 yr., and were in a deplorable condition. This shaft had never produced very good results when working prior to the shut-down at the time the war started, as the ore was not very high grade, but the European war had so increased the price for silver that the company thought perhaps we'd better try to work it, and see if it would not pay. The hoist, drum and cable had been painted over with chapopote to prevent rusting the cable. It certainly prevented rust all right, but it was almost impossible to get it limbered up so that the cable could be used.

After oiling and scraping for about two weeks, we finally got the cable unwound off the drums, and then started in on getting the joints of the hoist limbered up. We found that it was absolutely impossible to move the pistons in the cylinders despite anything we apparently could do. It was impossible to loosen the locknut on the rod and back the piston out, and we finally took the rod off at the crank, lined rods and connecting rods up in a line, and built a wooden set of guides for the end of the connecting rod to run in; then put the largest jacks against the end. In the meantime we had put back the cylinder heads and filled the cylinders with kerosene. After taking off the heads and applying the pressure with the jacks, I nearly despaired, but finally they let go and began to move. I hardly think one could say they had any rings left on them. It was just a solid mass of rust. We scraped the pistons, touched up the cylinders with a light rubbing of emery cloth, and made new rings for one piston, having been fortunate enough to find rings enough to fit the other one. The valves were also in bad shape but we ground and scraped until we had a fair fit and called that "good enough."

The boilers, prior to their shut-down, had carried 150 lb. of steam. I examined them carefully and took out a number of flues, refitted the old girl with brasses that I found in the waste heap, as neither of them had a valve or cock on them, both having been robbed during the revolution of all fittings. The safety valve gave me cause to fear, and after looking it over carefully, I decided not to tempt fate, but to hunt up another one and put it on. Back I went to the waste heap and found, not one, but a dozen that had been thrown there. Selecting one of the best looking ones, we put it on the boiler and tested it out. I put this boiler up to 225 lb. cold water pressure with a hand pump I'd rigged up. Then I backed the pressure down and set the safety at 70 lb.

The old boiler showed no signs of strain while under the test, so I proceeded to work the other one over in the same way. The tubes had quite some scale on them and I removed all that we could handily get at. This put our shallow workings in line as far as I was concerned, and I went back to the main works, trying to get this plant under way.

U. S. Civil Service Commission announces examinations for Senior Engineer, Grade 2, $2100-$2700, Civil, Electrical, Mechanical, Signal, Structural, Telegraph, and Telephone Senior Architect, applications to be rated as received until further notice, to fill vacancies in the Interstate Commerce Commission, under the act providing for the valuation of the property of common carriers and vacancies in positions requiring similar qualifications, at these or higher or lower entrance salaries. Applicants must have reached their twenty-fifth but not their fiftieth birthday on the date of making oath to the application. Age limits do not apply to persons entitled to preference because of military or naval service. Apply for Form 1312, stating examination title.

Foundation Notes

SATISFACTORY operation of an engine greatly depends on its foundation. If an engine engine builder sends out plans for the foundation, it is best to adhere closely to those plans and not "skimp" size or quality of material. Sometimes the purchaser, or his operating engineer, has peculiar ideas concerning what ought and what ought not to be; sometimes these ideas are good, but often they are a source of trouble to the man who erects the engine.

The foundation is supposed to be heavy enough to remain quiet when the engine is at work; should the soil at the bottom of excavation be soft, or of a quicksand variety or in any way not fitted to support a foundation, a subfoundation the character of which should be determined by the nature of the ground, should be built. One of my erection jobs was where piles had been driven, sawed off, and a large slab of concrete poured on top; this formed the subfoundation.

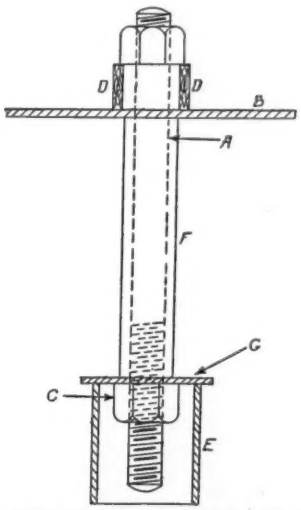
Always be sure to get the area specified in the plan. Sometimes, for some reason or other, we can take off a little in length and add on to the width, or vice versa, but it is best not to change too much.

When the forms are placed, they should be well braced to prevent anything moving or giving way when the concrete is poured. Care should be taken to see that all channels for piping, conduits, etc., are taken care of; and if various parts of the foundation are of different height, this should also be noted.

The template for the foundation bolts is very particular, for a bolt misplaced sometimes causes a great deal of trouble to say nothing of labor and expense. It is best to check up the locations of the foundation bolts after they are in place in the template, and it is well for a second man to do the checking; for often, if a mistake is made, the same man going over the work again, will make the same mistake.

Do not cement in the foundation bolts when constructing the foundation. Use something that will give the bolts plenty of play. I have had much success using this ordinary corrugated galvanized spouting; the 4-in. size will give play to bolts from 2 in. down.

On the bottom of the bolt should be a cage washer, containing a nut, this nut should be midway the length of the thread, on lower end of bolt. On the bottom of the cage washer should be a little box of some sort to keep out the concrete, and enable the bolt to be screwed up or down. In the sketch, A is the foundation bolt resting on blocks D, D, which represent the height that particular bolt is to stand; these blocks rest upon the template B. The nut C on the bottom is about midway of the lower thread, and held in the cage washer G while below is the box E. The galvanized pipe F surrounds the bolt, and extends from the cage washer to the bottom of the template, where it is centered around the bolt, and held in place by a few nails. So when finally the foundation is hard, the template removed, the bolt will be free to move sideways and also to be screwed up or down as the case may call for. This I consider quite essential. I have been on many jobs of erection when the foundation has been placed without sufficient attention given to these details and consequently had much trouble in getting things lined up. I have been where the bolts had been cemented in up to about 3 ft. from the top of the foundation; when the engine had been leveled up some of the bolts had to be



FOUNDATION BOLT IN POSITION FOR POURING CONCRETE

sawed off and others had thread but for half a nut. I have also often had to take a jack and get a heavy strain on a bolt, then get after it with a sledge to move it enough to get the engine lined up. In one case we had to take some off the top of the foundation as the bottom of the bolts had been bent at right angles and grouted in securely and there was not enough thread projecting through the engine casting for a nut.

It is not necessary to have such a large plate on the bottom of a bolt, if that bolt is grouted in when the engine is; and in grouting the engine, get it leveled and lined on iron wedges, then pour your grouting. After a few days, depending on amount of heat around the foundation and rapidity with which the grouting hardens, these iron wedges should be removed. This will let the engine rest upon concrete, and the nuts can be pulled down tightly on the bolts.

Recently I came across an engine which could not be held. Investigation showed that all the iron wedges

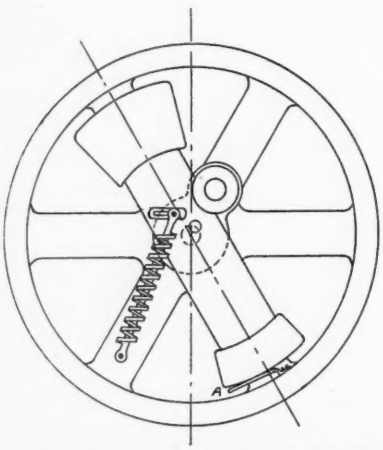
with which it had been leveled were still in place, and all the pulling on the foundation bolt nuts did not help hold it. It merely came a little tighter on the wedges.

I saw a uniflow engine recently whose vibrations shook the building. This was principally by the failure of the erector properly to set the supporting bracket under the cylinder. Much of this trouble could be eliminated by properly regrouting. TOM JONES.

Engine-Room Tribulations

JOSH BILLINGS, Confucius, or some other philosopher once said: "There's as much difference in some folks as there is in anybody."

We had that saying illustrated when we purchased a small unit, to take care of our night load when the main engines were shut down. The night load was comprised of two small electric pumps, running intermittently, a few incandescent lamps, and, once an hour, the watchman used a small electric elevator. The unit consisted of an 8 by 8-in. vertical, balanced-valve engine, using steam at 150 lb., cutting off at ¼ stroke, and running at 275 r.p.m. A flywheel governor, of a well known make (one of the best) and direct-connected to a 240-v., 20 kw. compound-wound generator. The unit and



FLYWHEEL GOVERNOR THAT KNOCKED WHEN SHUTTING DOWN

switchboard were assembled and the wiring and piping installed, all by home talent, and when all was in readiness the machine was started up.

From the start the pointer on the volt-meter began to oscillate and the lights to flicker, continuing to do so at all loads. Everything seemed to be all right as to speed regulation, so we started to search for the trouble elsewhere. As the generator was secondhand we went over the electrical end first, also testing the voltmeter on the main busses. This end was found to be O. K. The engine governor was next dismantled and all pins, spring, and small parts were examined. The eccentric and valve were inspected, and fresh packing put on the valve-stem, all to no purpose.

About that time, hearing that a representative of the engine company was in town, we telephoned, inviting him to call. He blew in, with all the dignity and importance of a representative-salesman-erector of a large firm of engine builders, shook hands, lighted one of our cigars, asked a few questions, and said, "Let her go!" We let her go.

While we tried various loads he watched the engine and voltmeter. After a few minutes he said: "That will do; shut her down. We will send you a heavier wheel." And went away.

We looked at each other and scratched our heads—none of us believed that a heavier wheel would turn the trick. In due time, however, the new wheel arrived and we rolled it on the scales. It weighed a little over 200 lb. more than the other one. After making the change and adjusting the spring in the new governor for 275 r.p.m. we started up the machine and it ran as pretty as a gold clock—voltmeter pointer and lights steady at all loads.

Can you beat it? After we veterans had monkeyed with that engine for over a week that young man saw in a few minutes what was needed. In shutting down, the governor arm hammered badly on the stop, but by setting out the steel brake spring a little harder at A in the sketch the arm came to rest quietly.

M. M. BROWN.

High Velocity Steam Mains

REFERRING to the Jan. 15 issue, I think Mr. Hurst's remarks on velocities in steam mains are likely to be misleading, as the tendency of which he speaks is, if anything, toward somewhat lower velocities than was the case a few years ago.

This has been due to finding in the operation of piping designed for high velocities and large drops in pressure that the resistances were usually underestimated and also that there were unexpected demands for more steam than the line was designed to supply. Our only measure of resistance is the drop in pressure at normal rates of flow so that we may say that the increased pressure loss in the line was directly proportional to the error in estimating the resistance; but for increased flows the pressure loss varies as the square of the velocity, so that if the flow increased only 20 per cent above that for which the line was calculated with a 20-lb normal pressure drop, the pressure drop would be $1.20^2 \times 20$, or 28.8 lb., and if the flow increased 40 per cent the pressure drop would be practically doubled. If such a condition occurred in a line supplying a turbine which was already pretty well loaded the resulting drop in inlet pressure would probably make things considerably worse and cause the turbine to lose speed badly. Then, too, it is seldom that plant development reaches such a stage that no further apparatus will be added on a steam line and where moderate velocities, say 6000 to 8000 ft. per min., are used, such arrangements can usually be made without replacing a whole steam line.

I doubt whether polishing the inside of steam lines would last very long, as it is only a matter of a few weeks until the whole inner surface of the pipe and fittings is covered with a rather closely adhering coating of fine red oxide of iron. This probably occurs from ordinary rusting of the inside of the pipe due to the air always present in the steam, at times when the flow is slow and some moisture present, and the cooking of this yellow brown slime to a hard red powder like crocus when steam is flowing rapidly and the temperature high.

Of the advantages listed for high velocities the only one of material consequence is the reduction in the cost of piping and its accessories as all the others can be obtained at very small expense and with probably much less ultimate inconvenience by suitable design. A very careful investigation of pipe coverings made at one of the technical schools and extensively reprinted shows that from an economic point of view most piping is inadequately covered, but also that proportionately less thickness of covering is required on a large pipe than on a small one, so that the heat loss of the larger pipe can easily be reduced to that of a smaller one.

The size of a boiler is purely a matter of heating surface and to deliver a certain weight of steam the same, or possibly slightly more, due to the higher temperature of its contents, is required at high pressures than at lower; not only this, but operating difficulties due to impure feed water are greatly accentuated at higher pressures, so I do not agree with Mr. Hurst on this point.

General opinion on flanged joints does not seem to agree with Mr. Hurst, as most recent large stations have used Vanstone flanges of one sort or another, about the only innovation being the leveling of the edges of the pipe lap and welding them together instead of using a gasket. The joint he shows is very expensive to machine and a solid copper gasket has too little elasticity for pipe work, not to mention the practical impossibility of so figuring the dimensions of the parts that the ground joint inside the groove and the copper ring would pull up tight at the same time.

The present status of power plant design is that we have practically reached the limit of our present materials of construction at about 650 to 700 deg. F. steam temperature and with this in mind one can obtain better thermo dynamic efficiency with as high pressure and as low superheat as we can arrange for, which is an additional reason for using reasonable effort not to waste pressure unnecessarily to move steam through the pipes.

The principal justification for very high steam velocities is with very large units to allow for holding down the size of pipe and fittings to what we know are safe and workable and even on these progress is being made in unit station design, multiple boiler outlets, etc., to reduce this limitation.

H. D. Fisher.

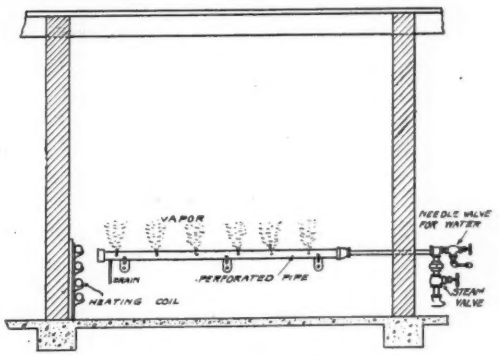
Low Temperature Steam Humidifier

In various drying processes such as varnish driers, glued panel redriers, etc., a condition is often required wherein the combination of a low temperature and a comparatively high per cent of relative humidity should be maintained.

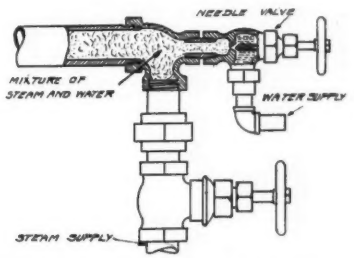
Usually, steam is the available agent from which the air will receive its moisture. In many cases, however, the steam temperature is so high that the temperature of the air within the room will become greater than is desirable.

The following method, as illustrated in the sketches herewith, has been more or less successfully applied to overcome the excess heat. In this case, a perforated pipe approximately twice the size of the steam supply is used as the distributor. A reducing tee can be set in the line at a convenient bend above the steam valve and close to the perforated pipe, to serve as a mixing chamber.

A needle valve will be connected into the tee as indicated in the drawing, through which the water will be supplied. The water should be at a comparatively high pressure in order that a fine mist will be formed when passing through needle valve orifice.



SECTION SHOWING HUMIDIFIER IN ROOM



DETAILS OF HUMIDIFIER AND FITTINGS

By the addition of the water mist, the steam temperature is reduced and is consequently better suited to the work for which it is intended in that it is more humid as well as being reduced in temperature.

C. H. Fuller.

Feed Line Trouble

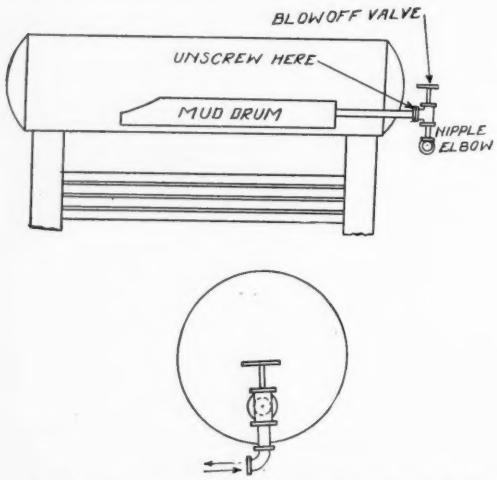
Some time ago, during the operation of our power plant it was found that our large duplex boiler feed pump was not giving the best of service, as it seemed very hard to keep enough water in the boiler.

I examined the pump and found that it was in good condition, and was still puzzled as to why I couldn't keep the water at a desired height in the boiler. I at once began to examine the water line going from the pump to the boiler. Just before the water enters the boiler, there is a check valve; upon examining it, I found that the seat of the gate valve located in the water line had been carried over and lodged in the check valve and there was only a small hole whereby the water could pass through into the boiler, about ¼ in. in diameter, whereas it should have been ¾ in. or more, and after removing it I have been able to keep the desired amount of water in the boiler with little difficulty.

Howard Laffoon.

Peculiar Blowoff Valve Accident

RECENTLY a Heine longitudinal-drum boiler was installed in a wood-working plant. The boiler was set up in the open and protected by a roof. The blowoff was not piped away from the boiler, simply a nipple and elbow were connected to the blowoff valve as shown in the sketch. In putting on the elbow, it was screwed up without thought of the possible effect it might have on the operation of the valve. It so happened that it was turned to the left and when the water and steam blew out through the elbow, the reaction of the jet pushed in such a way as to unscrew the valve, leaving the blowoff pipe wide open. This turning was so rapid that the man who opened the valve barely had time to get out of the way. Fortunately, the blowoff and mud-drum are located in the main drum of the boiler, so that after the water was drawn down to the level of the mud-drum, steam passed out leaving water in the legs and the tubes and on the bottom of the main drum, so that no damage whatever was suffered by the boiler.



ARRANGEMENT OF BLOWOFF VALVE WHICH GAVE WAY

Little time was lost in replacing the valve and needless to say great care was taken to leave the elbow pointing in such a way as to tighten the valve whenever blowing off.

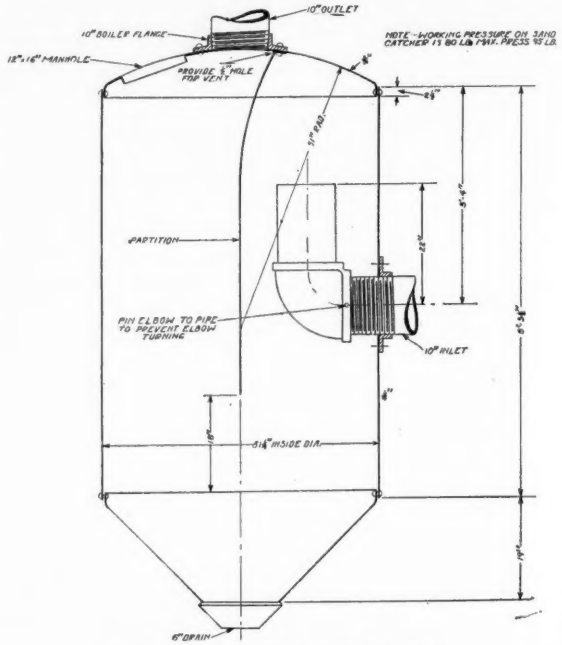
R. F. BURKE.

A Homemade Sand Trap

AT ONE of the leading sugar refineries in the West much trouble had been experienced with the sand from sand filters through which the fresh water was filtered before being used for the refining operations.

At the plant, as in all sugar refineries, a great quantity of fresh water is used for diluting, mixing, washing and rinsing the sugar and filtering media. The quantity of water used when the plant is in full operation being in the neighborhood of 3,000,000 gal. a day, all of this water is hauled by means of tugs and barges from up a river which flows into the bay on the shores of which the refinery is located. After being brought about 30 mi. in this manner, it is stored in tanks and cisterns and when it is drawn from these storage places it is pumped through a number of sand filters under a pressure of 90 lb. per sq. in.

After leaving the filters the water enters the distribution system in the refinery. It was thought a large quantity of the filtering sand was being carried over into the system. In order to catch this sand and prevent it from getting into the apparatus of the plant a sand trap was devised and installed as shown in the accompanying sketch. After the installation of this sand trap no further trouble was experienced, as the flush valve at the bottom of the tank was opened periodically and the trapped sand flushed out.



DETAILS OF HOMEMADE SANDTRAP

C. C. BROWN.

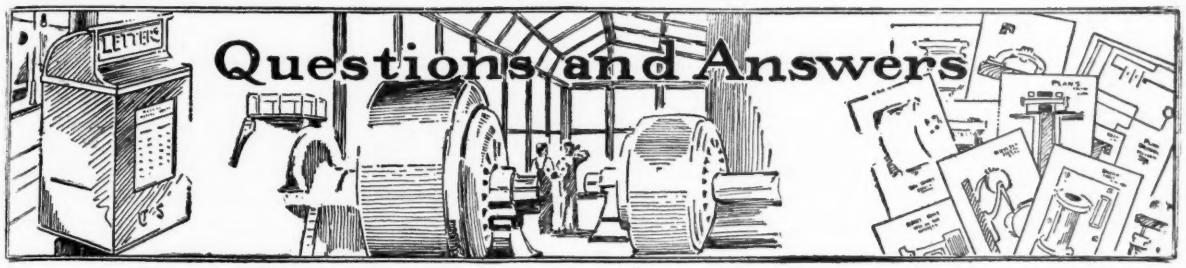
Packing Valves of Sprinkler System

WHERE automatic sprinkler systems are used for fire protection, there are usually a number of indicator post valves on the laterals where they leave the water mains. The stuffing-box on these valves is usually four or more feet underground and if packed with fibrous packing has to be dug up too often for the peace of mind of the man in charge. If allowed to leak in winter they are likely to freeze the upper part of the post solid, especially so in clay soil, making it impossible to shut the water out of the sprinkler section should necessity arise.

We have almost overcome this trouble by packing the stems with ⅜-in. gasket tubing such as is used in making the handhole and manhole joints on boilers. We have stems packed with this that have not troubled us in 4 to 6 yr. We usually smear the packing thoroughly with graphite and cylinder oil.

J. O. BENEFIEL.

IN AN address before the British Association J. D. Watson recently stated that experiments in Birmingham had shown the practicability of utilizing sewage gas as fuel in a gas engine. Gas derived from sewage sludge was used to drive a 34 hp. gas engine.



Stresses in Pipe Bends

I WOULD like to ask the readers of Power Plant Engineering to give me information on the stresses occurring in pipe bends caused by expansion and contraction due to temperature changes. I have in mind particularly problems in connection with high pressure superheated steam piping. C. C.

What Causes Leaky Tubes

I DO NOT quite agree with C. G. Harden on his subject in Jan. 15 issue: "What Causes Leaky Tubes" and would have done the reverse of what he did; that is, I would have dropped my grates farther from the boiler and made the combustion chamber deeper.

I would like to hear the subject discussed further, as it should be an important subject to the readers of Power Plant Engineering, both as to maintenance and fuel economy.

Steam boiler insurance companies should have data on this question, as it is of vital importance to them as well as to the operator.

H. L. W.

Setting for Burning Fuel Oil

IN THE Jan. 15 issue S. I. C. illustrates an oil-fired return-tubular boiler setting. He states that he gets an evaporation of 10 lb. of water per lb. of oil fired and that the oil has a heat value of 19,000 B.t.u. Also, he wishes to know if lowering the grate will increase efficiency.

An evaporation of 10 lb. of water per lb. of 19,000 B.t.u. oil and with the conditions of pressure and feed water temperature mentioned gives an efficiency (neglecting the loss due to the hydrogen in the fuel burning to water) of 53 per cent. This should be increased upward of 15 per cent with little difficulty.

I would not only lower the grate but would remove it entirely and put in a checker-work floor in which the air is preheated on its way to the furnace. Also the "deflecting arch" and the checker wall near the rear of the boiler should be removed because it is unnecessary. The blowoff pipe should, of course, be protected. The burners should be set so as to point downward slightly to avoid blow-pipe action on the boiler shell.

After these changes are made experiments should be carried on to determine the best operating conditions. Draft should be controlled by the damper and not by the ashpit doors. The oil should be preheated to a temperature well inside the point at which carbon deposition takes place, and the steam for atomizing should be superheated by passing it through a pipe in the smoke box.

Good results have been attained with oil-fired return-tubular boilers by filling up the combustion chamber to the level of the grate and covering with fire-brick. This has the effect of bringing the gases closer to the boiler shell with a consequent greater heat transfer by radiation, which, by the way, is a large part of the total heat received by a return-tubular boiler.

C. O. SANDSTROM.

Water Heater Capacity

I WOULD like to ask what you would consider the best method of heating water for a hotel of 200 rooms, every one of which has running water and nearly half, private baths. There is, in addition, a large amount of hot water used in the kitchen. We have no power plant as we use gas in the kitchen instead of steam and our elevator is run by electricity, which is supplied from the outside. Under these circumstances, I have been using large size hot water heaters, but find it difficult to get an adequate supply. We will have to install a third or else use another method of heating. As we do not use steam for any other purpose in connection with the hotel, I have been desirous of avoiding its use in connection with our hot water supply. I did not wish to make it necessary to engage a licensed engineer for a steam plant that is used only for heating water.

I might add that I have a storage capacity of about 1000 gal. When I drive the fire with open draft I find that we make considerable hot water and can, under such circumstances, supply our needs; but even at the time when our consumption is least, it is difficult to get such hot water without having our full fire on. In other words, with a moderate fire, we seem to get little hot water, apparently, not in proportion to what we get with a hot fire. Owing to the direct draft on these heaters and the lack of baffling, the consumption of coal with a full draft is great.

W. B. S.

A. Under the conditions given, you are probably using the most economical method of heating water that you could find.

Where a specific quantity of water is to be raised a certain number of degrees per hour, for special purposes, the boiler capacity must be figured as follows:

Multiply the number of gallons to be heated per hour by 8⅓ lb., which is the weight of one gallon of water, and this result by the temperature rise. Divide this result by 8000, the assumed number of heat units absorbed by the water per pound of coal fired. The result will be the weight of coal which must be burned per hour; this divided by the rate of combustion at which the boiler is to be operated, will give the area of grate required.

If, in your case, the use of hot water is intermittent and the heaters are not able to keep up the supply for short periods, it would be well to install a larger reservoir and give the heaters a chance to work more constantly.

If, on the other hand, the use of hot water is comparatively steady, it would show that the heaters are not large enough, and if that is the case, it would be advisable to discard the present heaters and install one with capacity enough to furnish the required amount of hot water.

We would suggest connecting a water meter in the supply pipe to the system and measure the amount of water used at different periods during the day and also for the whole day, together with the temperature of the water going to and from the heater.

This will give the necessary data on the capacity needed. If the water is not hot enough, more will be used than if it were at a higher temperature; but this will not make any difference in the total capacity wanted, as it is the amount of water, multiplied by the rise in temperature which determines the size of heater.

It will be necessary to get the average temperature of the hot water in order to determine the correct capacity.

There is no doubt but that a larger heater of some type may be found which will have capacity enough for your requirements.

A 1000-gal. tank is not large for two large-sized heaters, and it is possible that the tank is too small for good service. This tank would be about right for a heater or heaters with a total of about 6½ sq. ft. of grate surface, burning about 40 lb. of coal per hr.

The present heater, of course, should be examined and if necessary, cleaned of soot which constantly gathers on the heating surfaces and renders a heater or boiler inefficient. SAMUEL E. BALCOME.

Extraction of Roots

IN THE expression used for determining the size of pipe that should be used for a certain steam flow and pressure drop, which is given as

$$D = 0.203 \sqrt[5]{W^2 L \div p\,d}$$

how is the fifth root of the quantity under the radical found? In this equation D is the pipe diameter, W is the flow in pounds per min., L is the length over which the pressure drop p is allowed and d is the main density of the steam. I have particularly in mind a case where W = 200 lb., p = one lb. over a length, L, of 100 ft., pressure is 105 lb. abs. at which the density is 0.2365. J. M.

A. Probably the quickest way to extract the required root of the quantity given is by the use of logarithms. In this case it is just as well to perform the multiplication and division by the same method.

Substituting the numerical values in the above equation, we get

$$D = .203 \times \sqrt[5]{200^2 \times 100 \div 1 \times 0.2365}$$

The first operation is to reduce the quantity under the radical. The log. of 200 is 2.301 which, multiplied by 2, the exponent of 200, gives 4,602, the log. of 200^2. To multiply by 100 we add the log. of 100, which is 2, giving 6.602. Now to divide by 0.2365 we subtract the log. of this number, which is .374 — 1.

$$\begin{array}{r} 6.602 \\ .374 - 1 \\ \hline 6.228 + 1 = 7.228 \end{array}$$

To extract fifth root, we divide this log. by 5.

$$7.228 \div 5 = 1.446.$$

To multiply by .203 we add the log. of that number, which is .307 — 1.

$$\begin{array}{r} 1.446 \\ .307 - 1 \\ \hline 1.753 - 1 = .753 \end{array}$$

To find the answer we simply look up the number of which this is the logarithm, which we find to be 5.66. The nearest commercial size which would be used is 6 in.

The accuracy desired here is not great and consequently the logarithms may be found on a slide rule to three decimal places. Where greater accuracy is desired a six-place table should be used.

In looking up the logarithm of a given number, the figures found constitute what is known as the mantissa. They are the numerals that follow the decimal point. The figure in front of the decimal is called the characteristic and depends upon the number of digits in the original number, or, if a decimal, the number of zeros before the first significant figure. For a one digit number such as 1, 2, 3, etc., the characteristic of the logarithm is zero; for two digits, 1; 3 digits, 2; etc. Thus the logarithm of 100 is 2; of 10, 1; of 1, zero; of 0.1, —1; of 0.01, —2; etc.

Heat Loss in Flue Gases

SOME TIME ago I saw an expression for the heat lost in flue gases going up the stack which was given in the form: $L = 58.46 \times T \div CO_2$, where L is the heat lost per pound of carbon burned, T is the difference in temperature between the stack and atmosphere, CO_2 is the per cent CO_2 present in the flue gas.

Can you give me an explanation of this formula and the derivation with special reference to the constant 58.46? M. M.

A. For every pound of dry flue gas going up the stack, a certain amount of heat is carried away, depending on its temperature. The heat content above atmospheric temperature is equal to the difference in temperature times the specific heat or T × .24, 24 being the approximate specific heat of air or better the flue gases. Heat lost per pound of carbon burned would be W × T × .24 where W is the weight of dry flue gases per pound of carbon. When carbon burns to CO_2 the combining weights are as follows:

$$C + O_2 = CO_2$$
$$12 + 32 = 44$$

from which it is evident that for every pound of carbon burned there is required 1 × 32 ÷ 12 = 2.666 lb. oxygen. As air consists of 23 per cent oxygen by weight the air required is 2.666 ÷ 23 = 11.594 lb. This, of course, assumes perfect combustion with theoretical air requirements. When there is an excess of air, the per cent CO_2 in the flue gas would be less and the total

weight of air would be increased in the proportion that the per cent CO_2 is decreased, thus in general, weight of flue gases per pound of carbon equals 11.6 times per cent CO_2 with theoretical requirements, 20.9 ÷ actual per cent CO_2, i.e.,

$$W = 11.6 \times 20.9 \div CO_2 = 242.4 \div CO_2$$

The heat lost up the stack is then

$$L = 242.4 \div CO_2 \times T \times .24$$
$$= 58.46 \div CO_2 \times T$$

This equation assumes dry flue gases and perfect combustion with no carbon monoxide.

Surface Required in Brine Cooler

WE HAVE in our ice plant a double-pipe brine cooler where brine is cooled for making ice and for refrigeration. The compressor used is rated at 15 T., but we have difficulty in realizing that capacity and I am of the opinion that the cooler is too small. There are two banks of coils, 8 pipes high, 12 ft. long. The inner or brine pipe is 2 in. in diameter and the outer 3 in. What is your opinion on this subject? E. S. R.

A. A good method of checking the size of this cooler is to test for the coefficient of heat transfer through the brine pipe in B.t.u. per sq. ft. of surface per degree of temperature difference per hour.

One ton of refrigeration is equivalent to 288,000 B.t.u. per day or 12,000 B.t.u. per hr. With a capacity of 15 T. the heat transmitted to the brine is 12,000 × 15 = 180,000 B.t.u. per hr. The area of the brine pipe surface is 2 × 8 × 12 × 3.14 × 2 ÷ 12 = 100.48 sq. ft. The heat transmitted is then 180,000 ÷ 100 = 1800 B.t.u. per sq. ft. Assuming now a temperature difference of 10 deg. between the brine and ammonia, we find coefficient to be 1800 ÷ 10 = 180 B.t.u. per sq. ft. per deg. per hr.

The coefficient used by manufacturers and contractors in designing such coolers varies widely, depending largely on the temperature difference between the brine and ammonia and on the velocity of flow. The minimum and maximum seems to be about 50 and 150 B.t.u. respectively. If we assume the average of these, 100 B.t.u. per sq. ft. per deg. per hr., it will be seen that the factor 180 is 1.8 times too high or that the surface should be 1.8 times as great as it is. In other words there should be, instead of 16 tubes, 1.8 times 16 or say 29 tubes.

Boiler Capacity

IT HAS been suggested that we employ two marine type, horizontal fire tube boilers for use in a school building. Assuming that each is rated at 250 boiler hp., how much steam will each generate per hour at 90 lb. gage pressure, how much coal will they consume and what should be the grate area? J. N.

A. If each boiler is operated at the rated load it will evaporate the equivalent of 250 × 34.5 = 8625 lb. of water from and at 212 deg. per hr. The pressure, however, is not atmospheric but 90 lb. gage or approximately 105 lb. abs., and if we assume a feed water temperature of, say, 175 deg. F., the heat absorbed by each pound of steam will be different and the amount of water evaporated will be different.

Assuming the steam delivered in a dry saturated condition, the heat supplied per pound of steam is H — q, where "H" is the total heat of the steam under the given conditions (from steam tables) and "q" equals t — 32, where t is the feed temperature. Substituting then our values we find the heat added is

$$Q = 1187.2 - 175 + 32 = 1044.2 \text{ B.t.u.}$$

The amount of water evaporated will then be 8625 × 970.4 ÷ 1044.2 = 8000 lb. per hr. In this equation, 970.4 is the number of B.t.u. absorbed per pound of steam generated from feed water at 212 deg. F. at atmospheric pressure.

Assuming again now that we are burning bituminous coal having a heating value of 13,000 B.t.u. per lb. with an overall boiler and furnace efficiency of 60 per cent, for each pound of coal burned, the boiler will absorb 13,000 × 0.60 = 7800 B.t.u. The coal required will be 8000 × 1044.2 ÷ 7800 = 1070 lb. per hr.

For a general set of conditions, the rate of combustion is primarily a function of the pressure drop through the fire bed. If we assume a drop of about ¼ in. of water pressure, the amount of coal that can be burned per square foot of grate per hour will be about 20 lb. The effective grate surface necessary will then be 1070 ÷ 20 = 53.5 sq. ft.

Boiler Capacity: Pipe Expansion

HOW MUCH water would pass through a 100-hp. boiler, operating at rating, in 10 hr? How much coal should be required to evaporate that amount?

2. How would you determine the amount of expansion that will take place in a steam line and what provision should be made to take care of the expansion?

3. With a constant load on an engine and same spring in the indicator, what will be the difference in the area of the diagram running condensing and non-condensing?

G. A.

ANSWERS

A 100-HP. BOILER, operating at rating, would evaporate 34.5 lb. of water per hour from and at 212 deg. F. per hp., so that the total evaporation would be 100 times 10 times 34.5, or 34,500 lb. in 10 hr. The heat absorbed in this process would be 34,500 times 970.4 = 33,500,000 B.t.u. If you are using coal having a heating value of say 12,000 B.t.u. per lb. and are delivering 60 per cent of this heat to the water, you would require 33,500,000 divided by 12,000 divided by 0.60 equal 4650 lb. of coal during the 10 hr.

2. The coefficient of expansion for steel is 0.000,006,5, which is the amount, in feet, which one foot of steel will expand with a rise in temperature of 1 deg. F. If, for instance, you have a 50-ft. length of pipe in which there will be a temperature 200 deg. above atmospheric temperature, the expansion will be 50 × 200 × 0.000,006,5, or 0.065 ft., or 0.78 in. This expansion can be provided for by inserting in the line either an expansion joint or loop or offset so that there will be a certain freedom of movement.

3. With a constant load on an engine, and with the same indicator spring, there would be no difference in area of cards taken while running condensing and non-condensing.

POWER PLANT ENGINEERING

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Distributing Power Charges

Records showing how power is distributed among various places of consumption are of importance not only from an operating point of view, indicating what points of consumption are crowded and at what time, but also because of their value to the accounting department in allocating charges against the various departments of an industrial plant for power used in manufacturing. A public service corporation with many hundreds of points of consumption, can, as a rule, show, in terms of power units or dollars and cents, exactly how much power in various forms was distributed to each of the consuming points on the system. In central station practice this is, of course, absolutely necessary, since the sole object is the generation and sale of energy and, in order that the customer may be charged for the amount of power he uses, it is essential that such amounts be known to a fair degree of accuracy.

In this respect, the industrial power plant differs from the central station. In the former, the generation of power is not the all-important factor influencing profit and loss, and before the rise in cost of fuel altered conditions, power was distributed to the various departments of some industrial plants without any serious attempt being made to record the amounts. The total cost of generating power in such cases, was either added to the total manufacturing expense as a whole, or, was arbitrarily divided among the various departments in a more or less haphazard manner.

Such methods, however, were not only unscientific but extremely unbusinesslike and had no place in any otherwise well-managed plant. Previous to the war, fuel was cheap and the cost of power was a relatively unimportant factor in the total cost of production. Today, things are different. The price of coal has advanced enormously and the item of power expense is becoming increasingly important. As a consequence of this state of affairs, owners of industrial plants are becoming more and more desirous of obtaining records showing the relative quantities of power consumed by each department in order that such departments may bear their proper share of power expense. Such records not only aid in analyzing production costs but also make for more economical utilization of power.

The first method to suggest itself and also the most accurate, when a problem of this nature is to be solved, is that of equipping the various centers of consumption with meters, so that the power delivered to each center may be accurately measured. In a new plant this would be a simple matter and without doubt would be the method decided upon, but in an old plant which is built up largely of additions which have been added from time to time and where piping and wiring is, to a certain extent, interconnected, the meter method of solution has its drawbacks. Such plants often include certain departments where large quantities of live steam are used in process work or in certain steam consuming devices which exhaust at or near atmospheric pressure. Such exhaust steam is often used in conjunction with exhaust steam from the main generating units, for heating the factory buildings. Obviously it would be unfair to charge such departments for all the live steam delivered to them, since a great deal of the heat energy in the steam is returned to the common exhaust heating

system. Where a number of departments are interconnected in this manner or in various other ways, complications multiply and the problem of allocating the power charges correctly becomes correspondingly difficult.

How a problem of this nature was encountered in a certain industrial plant and how it was finally solved, is described in an article in the current issue by Wilfred A. Miller. Complex as the problem seemed at first, it is probably no different from that which exists in many other plants, and Mr. Miller's analysis of the situation, together with the results of his method, should be of interest to engineers in general.

Eliminating the Uncertain Human Element

"To err is human." The truth contained in this time-worn expression probably was realized by human beings long before it was first actually put into words, and in the picturesque language of the present day it may be said to be as "old as the hills," which, the reader will have to admit, is quite old. In spite of its antiquity, however, it applies equally well to the humans of this late day as it did to our prehistoric ancestor who probably first had it brought home to him when he failed in his attempt to crack Dinosauris over the "bean" at the critical moment, and, as a result, met with an early termination of his career.

Realizing the fact that none of us are infallible, a noted writer, Pope, we believe, made the expression read, "To err is human; to forgive divine." This, of course, provided us with a harmless anaesthetic to ease the pain of our shortcomings—it gave the erring humans an opportunity to ease their conscience somewhat.

We do not for an instant wish to detract from the excellence of the saying, but in engineering circles, while it may be divine to forgive, the problem is, rather, to make it unnecessary to forgive. In engineering work, the consequences of a mistake are often entirely too disastrous to be smoothed over by any mere process of forgiveness. It is related that a certain bridge collapsed simply because the designing engineer in his calculations forgot to multiply by two. That engineer, if the story is true, probably never forgave himself—nor did anybody else.

In modern engineering work, therefore, we strive to eliminate the human element to the utmost extent. A machine does not make mistakes; it may fail to operate, it is true, but by equipping it with suitable protective devices or alarms even this danger can be lessened to a high degree. The automatic boiler feed water regulator may be cited as an excellent device which has practically eliminated the danger due to low water caused by carelessness or inattention on the part of the water tender. All through the power plant, from the automatic coal handling equipment where the fuel comes in, to the sensitive protective relays on the switchboard where the electrical energy goes out, automatic devices have been installed which eliminate the factor of danger caused by erring humans.

The process of bringing a large synchronous motor up to speed, synchronizing it with the line frequency, and connecting the machine to the supply lines at the proper instant, is a task which usually requires the hand of a skilled operator. Even with experienced operators, machines of this type have been wrecked due to failure of the operator to close the switch at the correct instant.

In the new power plant of the Fisher Body Ohio Co. described in the pages of this issue, automatic features have been carried to the point where even the starting of synchronous motors is accomplished automatically. By the simple pressure of a button, the motor-driven exciter is started, the rotor of the large motor gradually brought up to synchronous speed and, at the proper moment, the main switch is closed, connecting the machine to the line. No knowledge nor experience is required—a child could do it without the least possibility of danger. The uncertain human element is entirely eliminated.

This, however, is only one of the numerous applications of automatic equipment to be found in this plant and the details should prove of interest to all those appreciating safety and reliability in power plant operation.

Power Plant Slogans

Keep and Analyze Operating Records in Every Power Plant.
Develop Water Power Sites.
Promote Health and Safety in Power Plants.
Handle Coal and Ashes Mechanically.
Employ Engineers for Engineering Work.

The Truth in Business

By Dr. Frank Crane

LISTEN, young man: The cleverest man in the world is the man who tells the truth and tells it all the time, not occasionally.

Sometimes you can profit by a lie, but it is like dodging bullets; you never know when you are going to get hurt.

Lying is a game. Sometimes it is a very exciting game. But it is essentially gambling; and gambling, any sort of gambling, is not business.

Exaggeration is lying. It does not take long for people to get the habit of discounting twenty-five per cent of all you say.

If you continually overstate and vociferate, you must keep on getting louder until you soon become incoherent.

But if you habitually state only what is soberly, honestly true, by and by everything you say will be away above par.

A man's repute for truthfulness is a part of his capital, so much so that he can raise money on it.

There is not one thing in this world that can be of as much value to you as building up a reputation such that men will say, "his word is as good as his bond."

It is well to be clever and keen and Johnny-on-the spot, it is well to look out for number one and to know a good bargain, but best of all is to have the world say of you: "Whatever that man says can absolutely be relied upon."

Copyright, 1921, by Dr. Frank Crane.

Filter for Flue Gas

EVERY boiler operator familiar with CO_2 equipment knows that the first requisite for successful operation is cleanliness and complaint is sometimes heard of the time required for blowing out the gas sampling lines and keeping the mechanism in clean condition. Realizing this situation, the Uehling Instrument Co. has been experimenting with many substances to perfect means for completely excluding soot and dirt from the gas sampling line.

Finally a material combining the necessary porosity and refractory qualities was found and this is now embodied in the new Uehling Pyroporus filter which is placed on the inlet end of the gas sampling line inserted in the flue or last pass of the boiler furnace. This filter consists of a heavy but highly porous disk held in a cup-shaped casting by means of a bolt. It is not injured by very high temperatures.

Formerly the gas was withdrawn through an open-ended pipe and the filtering was accomplished with cotton waste; this necessitated more or less blowing out of the gas line and required frequent renewal of the filtering material. With the new arrangement the soot builds up on the filter and does not appear to enter the pores to any extent, nor offer appreciable increased resistance to the gas flow.

PYROPORUS FILTER FOR FLUE GASES

It is not yet known what life may be expected of these filters, but present indications are that they will last for several years without any attention whatsoever. They are, however, inexpensive and are easily replaced. To facilitate inspection and replacement, the manufacturer has also developed a frame to be inserted in the brickwork and a holder for the sampling pipe. In the illustration the holder is shown detached from the frame. It is quickly fastened in place by two bolts. When the sampling line is to be inserted through a metal casing, as with a horizontal return tubular boiler, the frame is omitted and the holder is bolted directly to the metal casing of the boiler.

By this improved arrangement a smaller pipe line can be employed because its entire cross-sectional area is effective when it is kept clean. Smaller pipe is not only easier and more economical to install but, of even greater advantage, it takes less time to draw a given volume of gas through it and consequently the CO_2 recorder reflects furnace operating conditions more promptly when smaller pipe is used.

Pyroporus filters may be used for any make of CO_2 instrument and the frames and holders are useful in connection with pyrometers, draft gages and for providing convenient openings in the furnace for test and observation purposes.

New Limit Switch for Crane Operation

A NEW CRANE safety limit switch has recently been put on the market by the Westinghouse Electric & Manufacturing Co. This switch is designed to eliminate the undesirable features generally connected with the operation of a crane or hoist installation, when the hoist brake overtravels, resulting in the loss of

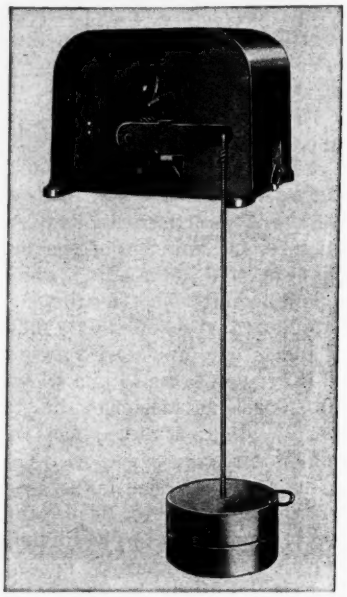

FIG. 1. LIMIT SWITCH HELD IN OPERATING POSITION BY MEANS OF A COUNTERSHAFT

production and often the injury of workmen due to broken cables, blocks and drums. The normal operating range of the hoist is increased, as it permits the handling of a greater amount of material, since there is no necessity of losing time by approaching the limit of travel slowly and cautiously. The safety limit guards the equipment irrespective of the kind of control or the position of the controller handle or brakes.

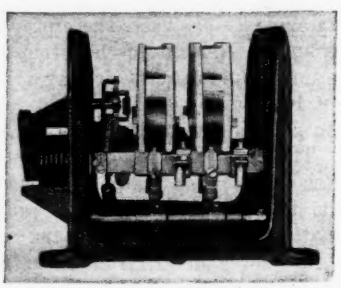

FIG. 2. STRONG TORSION SPRING OPERATES SWITCH

Under normal operating conditions of the machine, the limit switch is held in the operating position by the counter-weight as shown in Fig. 1, which overpowers the torsion operating springs. In case of overtravel, the counter-weight is raised by the hoisting hook or other moving part, which permits the strong torsion spring which may be noted in Fig. 2, to operate the switch. This disconnects the motor from the line and establishes a

closed dynamic braking circuit through the motor armature, motor series field and resistor, which stops the motor, irrespective of the position or type of the controller or brake. The operation of the switch also releases the series magnetic brake which holds the load until the controller handle is moved to the lowering position. As soon as the hook has been lowered beyond the limit, the switch is again ready to function as before, as it resets itself automatically. The quick-make and quick-break feature of the switch throws it rapidly from the normal to the breaking position when approaching the limit and back to the normal operating position when backing out. It will not remain in a partially open or partially closed position and destroy the contacts or fail to function.

The application for these limits is mainly for controlling the travel of the moving parts of the hoisting machine; however, they may be used on metal mixers, bridges and other applications employing series motors, where it is desired to limit the travel in one direction by applying dynamic braking.

Mountain States Ice Manufacturers' Association

By J. B. Dillon

THE Mountain States Ice Manufacturers' Association held its eighth annual convention in Denver, Colo., Jan. 13 and 14. More than 100 delegates from Colorado, Wyoming, New Mexico, Western Kansas and Western Nebraska attended.

President G. M. Smigelow, of Raton, New Mexico, said that the principal questions to come before the meeting would be the completion of plans for a national advertising campaign along the lines of those formulated by the National Association of Ice Industries at the meeting held in Chicago, October, 1921, and to endeavor to improve the grade of ice, increasing the consumption.

The delegates voted to affiliate with the National Association, appointed a committee on advertising and they will report to the executive committee at a later day.

In the election of officers for the ensuing year, M. Charles Salit of the Denver Ice Co. was elected president; Clarence Adams, of the Colorado Ice Co., vice-president; Floyd Vandewark, of Fort Collins, Colo., secretary-treasurer.

Leslie C. Smith of the National Association addressed the convention on "The National Publicity Program."

News Notes

The Skinner Engine Co. announces that it has placed its account for the Pittsburgh territory in the hands of the Andrews-Bradshaw Co., 812 B. F. Jones Building, Pittsburgh, Pa.

Mutually satisfactory arrangements have been made between the Combustion Engineering Corporation and the George J. Hagan Co., of Pittsburgh, whereby the Hagan company discontinues representation of the Combustion Engineering Corporation.

The Combustion Engineering Corporation has opened its own office in the First National Bank Building, Pittsburgh, Pa., and will soon open an office in Cleveland, Ohio, both of which will be in charge of W. C. Stripe, former manager of the Philadelphia office.

The George J. Hagan Co. will retain the exclusive agency for the Type "H" stoker, formerly known as the American stoker, for use in Hagan industrial furnaces.

D. B. Frisbee, of Atlanta, Ga., has been given the responsibility of developing a large selling organization throughout the South for Barber-Greene Co., Aurora, Ill.

Ford, Bacon & Davis, consulting engineers, specializing on power plant design, have opened an office in the Continental and Commercial Bank building, 208 South LaSalle street, Chicago.

Dayton-Dowd Co. announces the opening of a district sales office in Pittsburgh at 809 Keenan Building which will be in charge of T. J. Barry, who for the past several years has been connected with the home office at Quincy, Ill., on engineering and sales.

The Buckeye Boiler Skimmer Co., of Toledo, Ohio, has appointed Peter P. Beck its Eastern representative with offices at 3636 Grand Central Terminal Building, New York City. Mr. Beck succeeds W. F. Cremean, with offices at Wilkesbarre, Pa.

The Hardinge Co., 120 Broadway, N. Y., has acquired the pulverized fuel department of the Quigley Furnace Specialties Co. together with the organization of the engineering department. O. M. Rau, formerly with the Philadelphia Rapid Transit Co., will specialize in pulverized fuel problems and W. O. Renkin will be managing engineer of the department.

Kennedy Valve Mfg. Co. announces that H. D. Kane has been appointed assistant to C. A. Burgess as traveling representative with headquarters at Elmira, N. Y. James P. Murphy has been appointed assistant to S. C. Mead, Chicago branch manager. John J. Milliken, who has been in the Chicago office, has been appointed assistant to E. H. Koons, eastern sales manager. An additional office has been opened in the L. C. Smith Building, Seattle, Wash.

The officers of the Steam Motors Co. on Jan. 1 sold to the London Steam Turbine Co., of Troy, N. Y., all of its assets, patents and interests. Mr. London, who was the president of the Steam Motors Co., and a turbine engineer of international reputation, will occupy the same position with this company.

Mr. De Leon, the vice-president and general manager, brings to the company an experience of 25 yr. as a manufacturing executive with some of the largest concerns in the country.

The Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa., announces that T. H. Hays has been appointed manager of the Indianapolis, Ind., office of the company.

Until further notice, A. E. Hitchner, assistant to the manager, Industrial Department, in general charge of the Mining and Electro-Chemical industries, will have general charge of the sections, formerly handled by W. H. Patterson, who recently resigned as assistant to

the manager of the Industrial Department to accept the position of vice-president of the Kaestner & Hecht Co., Chicago.

THE UNIVERSITY OF MISSOURI at Columbia, Mo., will receive bids Feb. 24, 1922, on a power plant building, including smokestack, tunnel, boilers and stokers, traveling crane, steam and water mains, piping, etc. Applications for plans and specifications may be made to Edward E. Brown, business manager, Columbia, Mo. Deposit required, $10.

Other buildings to be erected, plans now in preparation, are: Agricultural building (stone), $200,000; Chemistry Building (stone), $125,000; Women's Gymnasium (stone), $150,000; Medical Building—Extension (brick), $35,000; Hospital Building (brick), $250,000; Mechanic Arts Building (brick), $50,000.

WILLIAM A. DURGIN has been granted a year's leave of absence from his duties with the Commonwealth-Edison Co., of Chicago, to assume direction of a new division in the Department of Commerce on Simplified Commercial Practices, to eliminate waste.

Books and Catalogs

SWITCHING EQUIPMENT FOR POWER CONTROL, by Stephen Q. Hayes; first edition, size 6 by 9; cloth, 470 pages, 276 illustrations; New York, N. Y., 1921.

This book fills the need for a work covering the general subject of switching equipment. While information on the subject of switchboards and switching equipment can be found in more or less condensed form in electrical handbooks, and while articles in the technical press also furnish a certain amount of data on the subject, there has been no American book devoted exclusively to the subject.

The material contained in this book is based largely on a number of articles written by the author which have appeared from time to time in a number of technical periodicals. These have been rewritten and brought up to date.

The book presents the kind of information the switchboard operator needs to help him keep the equipment in his care in the best operating condition by explaining what should be expected of the apparatus and equipment. It also contains information of assistance in the selection and installation of new material. Enough of the theoretical side of the subject is given to define the functions and limitations of the various devices. The apparatus described is that of the largest American electrical manufacturers.

The topics covered by this book are as follows: descriptions of switching apparatus; the main connections desired in a power plant; how to obtain the maximum amount of security and flexibility with the minimum outlay; switching panels; control desks, etc; location of breakers, insulation, structures, etc.; general arrangement of the part of the power plant devoted to switching equipment.

BULLETIN No. 124 of the Engineering Experiment Station of the University of Illinois, entitled "An Investigation of the Fatigue of Metals," is a progress report of the first part of an investigation by the co-operation of the National Research Council Division of Engineering, Engineering Foundation, and the Engineering Experiment Station of the University of Illinois, having for its object the determination whether or not there exists any clearly defined relation between static properties and ability to resist repeated stresses. As it was decided not to enter the field of non-ferrous metals at this time, a series of tests of materials well scattered over the field of ferrous metals was made, and in most cases two or more distinct heat treatments for each metal were studied. The results of these tests, and the conclusions to be drawn therefrom are given in Bulletin No. 124, copies of which may be had without charge by addressing the Engineering Experiment Station, Urbana, Illinois.

A NEW CIRCULAR demonstrating the comparative projecting power of the "Bayer" gun barrel type of nozzle was lately received from the Bayer Co., St. Louis, Mo.

"DURABLE" duplex pumps are the subject of a booklet from Dean Bros. Steam Pump Works, Indianapolis, which also contains various tables, hints on hydraulics, etc., instructions for setting valves and setting up and running pumps.

RIDGWAY Dynamo & Engine Co.'s latest bulletin, No. 30, deals with the company's motor-generator sets, illustrating and describing a few typical sets and calling attention to many interesting features of design and operation.

ARC WELDING for repair and reclamation, general applications of arc welding, and arc welding for manufacturing processes are described and illustrated in Leaflet 1825, just published by the Westinghouse Electric & Manufacturing Co. A story is told of how costs are reduced by the use of arc welding.

BULLETIN No. 343, prepared and issued by the Holophane Glass Co., describes in detail the new Holophane Lightmeter. This is an accurate, portable instrument designed for the measurement of foot candles, lamberts, candles per square inch, candle power, etc. A 3.8-v. tungsten filament lamp, fed by a small dry battery serves as a standard of comparison. The lamp, battery, rheostat and milliammeter are compactly assembled in the form of a tube, the rheostat being arranged so that it may be operated by turning the milliammeter about its axis.

While no new principles have been used in the construction of this Lightmeter, an extremely compact, light weight instrument has been produced. Its small size in no way impairs its accuracy.

BULLETIN No. 360 issued by the Jeffrey Manufacturing Co. featuring a portable car unloader for unloading coal from hopper-bottom or gondola types of railroad cars has just been received. The design of this unloader is such as to enable it to meet various conditions of unloading. It is so constructed as to require but a minimum of space in which to operate and can readily be placed in between the car hopper door and the rails. Where conditions permit, a more permanent arrangement can be had by placing the unloader underneath the rails and thus eliminate the necessity of resetting it for each car. It is in reality a double purpose machine since it will load directly into a motor truck, or can be extended to serve a storage pile by use of a separate portable conveyor.